University of Alberta

An Investigation into the Implementation of a High School Science Program with an STS Dimension

by

Stella Kilian-Shrum

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Education

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Stella Shrum

August 30, 1996

11 Escalier Place

St. Albert, Alberta

T8N 5T1

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *An Investigation into the Implementation of a High School Science Program with an STS Dimension* by Stella Kilian-Shrum in partial fulfillment of the requirements for the degree of Master of Education.

Dr. Wytze Brouwer (supervisor)

Dr. Brenda Gustafson

Dr. Maryanne Doherty-Poirier

Dedication

This work is dedicated to the memory of my parents who instilled in me the love of learning and respect for others' points of view.

Abstract

This thesis is a written account of an attempt to gain some understanding and insight into what it is like to be a science teacher in Alberta implementing an integrated science course with an STS dimension, Science 10. The viewpoints of students involved in the field validation of the program are brought into the discussion to expand the sources of information and to compare them with the teachers' responses. Also included is a brief description of the curriculum development process that culminated in Science 10, a comparison of Science 10 with the courses it replaced, and a discussion of how teachers incorporate a curriculum change into the classroom. For the teachers in this study, implementing Science 10 required that they adjust their view of themselves as discipline-specific teachers and determine what it means to incorporate "STS connections" into their classroom instruction.

Acknowledgments

The four teachers (given the names Ann, Beth, Colin and Dan in this thesis) who were kind enough to let me enter their classrooms and who shared freely with me their personal reflections of teaching made this work possible. As well, the teachers who took the time to complete the questionnaires and return them to me provided important information that made this a more comprehensive study. I wish to acknowledge, also, all the teachers who took part in the field validation and implementation of the new science programs for my interactions with them provided further insight into what it means for a teacher to implement a new science curriculum.

This work could not have been completed without the support and help of my family. I would like to thank my husband, John, and my sons, Steven and Jeffrey, for their patience and understanding. Thank you also to my extended family and the many friends and colleagues who provided support and ideas.

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"There is nothing more difficult to carry out and more doubtful of success, nor more dangerous to handle than to initiate a new order of things."

Machiavelli in The Prince

Chapter One

The Context

In 1992, the first of the revised and renewed science programs for senior high school students, Science 10, was implemented in Alberta schools. This move followed five years of intense development work by Alberta Education in consultation with teachers and other community members to develop a program of studies with a science, technology and society (STS) dimension. It was the first time in the history of curriculum development in this province that so many stakeholders were directly involved in the process and that such close scrutiny was focused on the curricular documents that were produced. In Alberta, curriculum development is an open process, but centralized with the Ministry of Education. The resulting programs of study are legally binding for implementation by school jurisdictions. In addition, students in their school-leaving year must write standardized examinations for core subjects, worth fifty percent of their final assessment mark. Within this context of accountability, teachers must bring the intended curriculum to life in the classroom.

This thesis is a written account of an attempt to gain some understanding and insight into what it is like to be a science teacher in Alberta implementing an integrated science course with an STS dimension, Science 10. The viewpoints of students involved in the field validation of the program are brought into the discussion to expand the sources of information and to compare them with the teachers' responses. Also included is a brief description of the curriculum development process that culminated in Science 10, a comparison of Science 10 with the courses it replaced, and a discussion of how teachers incorporate a curriculum change into the classroom. For the teachers in this study, implementing Science 10 required that they adjust their view of themselves as discipline-specific teachers and determine what it means to incorporate "STS connections" into their classroom instruction.

Personal History

In 1988, I became a member of the science team hired by Alberta Education to review and renew the science school programs for students in the province. The journey that I took to get to this point in my life is, I believe, not unlike that of many science classroom teachers of the "baby boom" era. As a child beginning school in the mid 1950s in a small rural community in Alberta, I was introduced into a culture in transition from agriculture as the economic mainstay to the beginnings of industrialization on the Prairies, with the major discoveries of oil and natural gas. I can recall the difficult decisions my parents had to make regarding whether they should lease part of their land to an oil and gas company to add to their income at a time of uncertain grain prices, knowing that it would shrink their harvest by taking land out of production. At this time, as global communication increased, the news of the first trip into space and the cold war arms buildup had become part of everyday conversation among the adults. At school, we were given plans for bomb shelters to take home to our parents and went through drills on how to prepare for the event of a nuclear attack! The first time television entered our home, I was in Grade 3.

I believe a combination of circumstances led to my keen interest in science: the science that was so obviously present in the everyday life on a mixed farm, the science I learned in school, and the positive portrayal of science in the media. I was interested in the germination tests my father did on the grain samples before seeding each year, the day-to-day activities of the farm animals I had to feed and water, my mother's garden, how we made butter out of cream, jam from the berries we grew, how the milk separator worked, and the dozens of machines my father used and repaired. I was at my parents' side when they candled eggs, built sheds, milked the cows, baked bread, and mixed formula for the young calves. This was science in action and it was fascinating to me.

At school, we learned practical science until Grade 9. I can clearly recall studying the operation of a lift pump for the Grade 9 provincial examination and seeing the relevance of this because we had such a pump at home. The media reported with great hoopla on rocket launches into space and major hydroelectric projects, while advertisements extolled the virtues of electric power and products made from oil. Nylon fibre was described as stronger than steel yet fine enough to make women's stockings, while

polyester was the wonder fabric that would eliminate wrinkles and make ironing boards obsolete.

This was the era of the *Sputnik* launch. Science and technology were wonderful according to the media, but apparently school science was not. North Americans were not producing enough scientists and engineers to stay competitive, and the general public knew too little about the workings of science. By the time I reached high school, the "alphabet" science courses, developed in other parts of the world, notably the United States and Great Britain, had filtered down to the courses taught in my small rural school. I was learning biology, chemistry, and physics devoid of societal context, except for the teacher's brief mentions of practical applications. The textbooks contained facts and questions to answer, based on reading the text. This was science and I was good at it—better than anyone in my class. In high school, I decided I wanted to be a scientist—a chemist—totally unaware of both the personal sacrifice this would require and the fact that at that time there were only a handful of women who were (Ph.D.) chemists in Canada.

By the second year of university, disillusioned by the realities and disconnectedness of undergraduate life at a large university, and convinced that my marks were not high enough to continue in science beyond the Bachelor's level, I questioned a career in science. The word around campus was that you could not expect to land a good job, perhaps not any job, with only a B.Sc. or B.A. degree. There were too many competitors around—all those baby boomers like myself—chasing too few jobs. What to do? I decided to become a science teacher. I enrolled in a broader range of courses to complete my B.Sc., partly because I thought this would make me a better teacher and partly because I did not find university chemistry particularly interesting. Then I enrolled in the one-year, after-degree program for teachers. My first job was as a chemistry and general science teacher in a large urban high school in Ontario. It was the most enjoyable time I had ever experienced; any regrets about not continuing to pursue my dream of becoming a scientist disappeared from my thoughts. The possibility of instilling in these young minds the wonder of science was euphoric. The students responded to my lessons, and I felt I was really making a difference.

It was not long before I felt I did not know enough to satisfy my students. The questions they asked were very good ones, but I did not have all the answers. This bothered me; a teacher was supposed to know everything, I thought. When a student

asked me where all the energy of an atom bomb came from, I could not answer in any intelligent way. Another student asked me what metallurgy was? Another wanted to know why the lake they had lived nearby all their lives had recently become green with scum? Why had four years of university education not prepared me for this? At about this time, I read Rachel Carson's book *Silent Spring*, and the terms "environmentalist" and "pollution" became common in the mass media. I began to question the god of science I had constructed and what we should be teaching students in science. While the earth was being denigrated by industrial pollution and threatened by governments with nuclear bombs, we were teaching students how to balance equations and do stoichiometry problems. Was this preparing them for the world they would inherit? Should I go off on a tangent and teach my students differently or bow to the peer pressure of my colleagues to give my students the rigorous science facts and problems? I tried to do both. My classrooms were noisier and my students sometimes did not do as well as the common exam. Word among students was that if you were going to study science seriously at the postsecondary level, you might want to enroll in another teacher's class. This was devastating to me, so I made my students work harder to "catch up". I realized that teaching for science literacy was not an easy task.

When I returned to Alberta in 1977, the senior high school science programs had undergone a change. I was assigned to teach chemistry and biology in a large rural-urban school. There were great opportunities within this curriculum, I thought, to teach students more than the facts of science—it was clear from the general objectives that students were to understand the relationship of science to industrial processes and to the environment. Within the elective portions, there were wonderful opportunities to relate science to their lives. I was elated. By the end of the year I realized that the requirements of the core program and the lack of good resources made it difficult to do justice to the elective portion of the curriculum. Several years later, the reintroduction of provincial examinations, which tested only the core material, finally discouraged those of us who were still trying to maintain the electives.

Several years later, I was at home being a parent, but still thinking about what was the best way for youngsters to learn science. I had completed and submitted a questionnaire in 1984 in response to the government request for public input into education in which I reiterated my position that students need a rigorous, but relevant, science program. Interacting with small children—my own and the neighbours'—reinforced for me the efficacy of the "hands-on" approach to inquiry for garnering enthusiasm and interest in

science, but it was a particular incident that galvanized my belief in teaching more students the science they need to deal with everyday events and decisions. I was in my acreage garden with my two small children when a small airplane began circling the adjacent wooded area, dropping clouds of vapour. I quickly took my children inside and began to investigate. Some of my neighbours had hired this pilot and his small airplane to apply the insecticide malathion to control tent caterpillars. I was alarmed that such a large-scale "chemical fix" was being implemented to solve what I believed to be a nuisance, with little understanding of the possible impact on the surrounding ecosystem, water systems, and human health. I began to try to educate my community, dropping letters in each mailbox and writing to the local newspaper. There was not a great deal of support for my point of view. This was when I renewed my resolve that scientific literacy should be a significant goal for school science education.

Societal Context

Not since the *Sputnik* era has so much attention been paid to what children are learning in school science—but for different reasons. In the 1950s, during the time of the Cold War, Western society's greatest concern was with maintaining an edge in science and technology in order to stay ahead in the arms race. Today, many government leaders regard knowledge of science and technology as providing an economic advantage. There is concern that the Western nations are not producing enough scientists and engineers and that the knowledge of science among the general public is inadequate. Furthermore, students describe studying science as uninteresting and irrelevant to their lives. Some leaders in science education suggest that the analysis of issues of public concern in science classrooms can do a great deal to foster the knowledge, skills, and attitudes required of responsible citizens, as well as motivate students to study and enjoy science.

Science has been one of the most significant factors in shaping our culture and our understanding of the modern world. The contributions of science to medicine, food production, war, transportation, industrial production, and human comfort are phenomenal and are continuing at a rapid pace. Not all the contributions of science have been positive. The problems faced by humanity today are global in nature and without national boundaries: the issues of ozone depletion, habitat destruction, acid rain, soaring human populations, huge gaps between the rich and poor nations, sexually transmitted diseases, just to list a few, are complex problems with no simple solutions. Many see scientific and technical progress as both the cause of, and the solution to,

many of these problems. An understanding of basic scientific concepts and the ways in which scientific knowledge is developed has almost become a requirement of everyday life and decision making.

All of Earth's citizenry must become involved in finding solutions to problems and resolving ethical dilemmas related to science, and they must be given the opportunity to attain the knowledge, skills, and attitudes needed to use science and technology wisely in order to promote the greatest benefit and cause the least harm. We need the diverse abilities and perspectives of many people to navigate the uncertain waters that lie ahead. Although it is overly idealistic to believe that education will solve all of humankind's problems, many of today's leaders and educators believe that providing all of our young people with a quality science education is of the utmost importance in contributing to a better world. Most agree that science deserves to be an important aspect of education, but what do students need to know about science? Scientific literacy may never be more crucial than it is now; however, debate surrounds the question: what does the scientifically literate person need to know and what skills does he or she need? It is within this context that changes were and are being made to the science programs in many parts of the world. In Alberta, the process had its inception in 1984 and continues today.

Historical Context

This brief historical account of the development of the new senior-high science programs in Alberta is presented from my perspective as a curriculum developer. Significant events of the time period from 1984 to 1992 raised the awareness of teachers and the entire community interested in science education, causing both to examine their views of science education and their role in it. As the researcher directly involved in the events that took place, I feel that I cannot consider the experiences of classroom teachers outside of this context. My experiences have coloured my perception of the role of teachers in curriculum development and made me much more aware of the various influences on educational reform.

Two studies were central to initiating the changes to the structure and substance of the secondary science programs in Alberta, while a third helped to solidify the resolve of curriculum developers to continue with the reforms in the same direction. The first indication that a change was contemplated for science education in Alberta came in 1985 with the publication of the report entitled *Secondary Education in Alberta*. This policy

statement summarized the findings of the review of secondary education begun in 1984. A questionnaire distributed to 856,000 households garnered over 10,000 responses, while other Albertans and groups presented briefs, wrote letters, and phoned the Department of Education. A representative group of students was also asked about their views, and a special advisory committee provided the Minister of Education with further advice. The principles and objectives summarized in this report were consistent with the Government's White Paper, *Proposals for an Industrial and Science Strategy for Albertans 1985–1990*, published in 1984, which stated that "Education should foster ideas of risk-taking, innovation and pursuit of excellence."

The policies outlined in *Secondary Education in Alberta* recognized the need for change to prepare our youth "to tackle the most difficult problems which our society faces and to shape the course of the future by their actions." This document outlined principles that are also reflected in the goals for secondary schooling and in the statements that were to guide future changes to programs and organization in secondary schools. In this policy statement, the stated goals of secondary education were (a) to give students a better understanding of the nature of science and technology and of their interactions with one another and with society; (b) to help students become responsible citizens and use scientific knowledge carefully; and (c) to prepare students for the world of work and their pursuit of further postsecondary studies in science. Specific recommendations for science contained in the report were as follows:

- a minimum of two science courses should be required to attain a general high school diploma
- a review of the curriculum for science should be undertaken to ensure that the content levels and objectives are appropriate.

In April of 1984, the Science Council of Canada published the second significant document that was to influence the development of the science programs in Alberta. Its thirty-sixth report, *Science for Every Student - Educating Canadians for Tomorrow's World*, was the result of four years of study into science education in Canada. The chairman of the research committee, E. Lawson Drake, described the research program as "one of the most comprehensive programs of original research in Canadian education." At the outset the council stated its belief that "it is of national importance that Canadians receive a quality education in science and technology...for Canada to cope with the social changes rooted in highly specialized technologies...and the new basics of our contemporary culture: science and technology" (Science Council of

Canada, 1984, p. 9). The council also encouraged the goal of "scientific literacy for all," stating their position that not enough students were receiving a quality scientific education. The report outlined several shortcomings of the current science education programs, which are summarized as follows:

- an inadequate or nonexistent science program for elementary students
- lack of challenge for high-achieving students
- little attention paid to the interactions among science, technology, and society
- curriculum and careers seen as irrelevant and uninteresting to many girls
- teachers complain of inadequate inservice programs
- little incentive for older teachers to be innovative or strive for excellence.

(Science Council of Canada, 1984, p. 10)

After considering these findings, the Science Council made the following recommendations:

- the guarantee of science education for every elementary school
- an increase in the participation of young women in science education
- the challenging of high achievers and science enthusiasts
- the presentation of a more authentic view of science
- the emphasis of the science-technology-society connection
- the setting of science within a Canadian context
- the introduction of technological education
- an assurance of quality in education.

(Science Council of Canada, 1984, p. 11)

In the context of the recommendations of these two studies, revisions to the Alberta senior high school science programs began in 1987. A project manager was assigned, and he and an assistant began some background studies and formed committees of teachers to review and revise the current science curricula for Grades 7 to 12. New integrated science programs for senior high school students were also to be developed. The first was an integrated science program for academically inclined students in Grades 10 to 12. This was the cohort of students who planned postsecondary studies after high school. The Science 10 program would serve as a prerequisite for revised discipline-based studies in biology, chemistry, and physics for students in the last two years of high school, while the Grade 11 and 12 integrated science courses would serve as a prerequisite for postsecondary studies in nonscientific areas, such as arts and business, without further study in the disciplines. The second integrated science

program proposed was a general stream program for Grades 10 and 11, designed to meet the new graduation requirement of two science courses, aimed at students who would not likely pursue postsecondary studies.

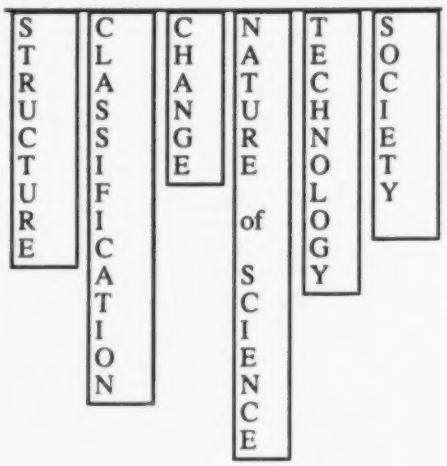

Figure 1. Pillars of Development for Chemistry 20-30.

All new and revised courses were to focus on major concepts, referred to as pillars of science (Figure 1), foster a hands-on approach to learning science in the classroom, and incorporate outcomes related to the connections of science concepts to the nature of science, technology, and how societal factors intersect with them. The additional goals of the programs were to motivate students to study science and help them to see how to apply science to their everyday lives and communities. The committees completed their preliminary work by September of 1988 and produced an outline of the concepts, skills, and attitudes that would be used as guidelines for writing the learning outcomes for each of the senior high school science programs. Information about the changes to the structure of the high school science programs had been disseminated to schools the previous spring. Each course was to be offered for the full five credits, or 125 hours (Figure 2).

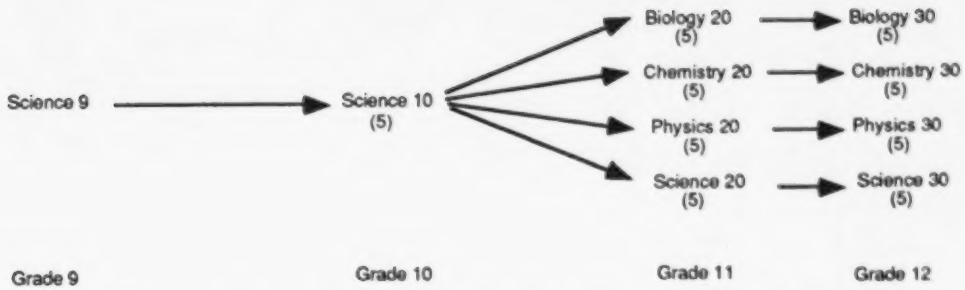

Figure 2. Proposed Program Structure for Academic Science Courses (Spring 1988)

In response to this proposed structure, high school administrators and the Alberta Teacher's Association (ATA) shared a common position, by disagreeing with it. They said that students in Grade 11 who wanted to take several science courses would have to incorporate into their timetable up to three full-credit science courses as well as a newly developed career and life skills (nonoptional) program called CALM 20. This, they said, would make it difficult for these students to fit complementary (optional) courses into their timetables. Numerous letters recommending against this structure for science were written to the Minister of Education by influential stakeholders, many representing the humanities. These were the first of the large number of letters that would eventually reach the Minister's office regarding the senior high school science revisions. Alberta Education officials became convinced of the point of view of the administrators and the ATA, and the structure was changed so that each of the Grade 11 science courses would be offered for half the credits, or 62.5 hours (Figure 3).

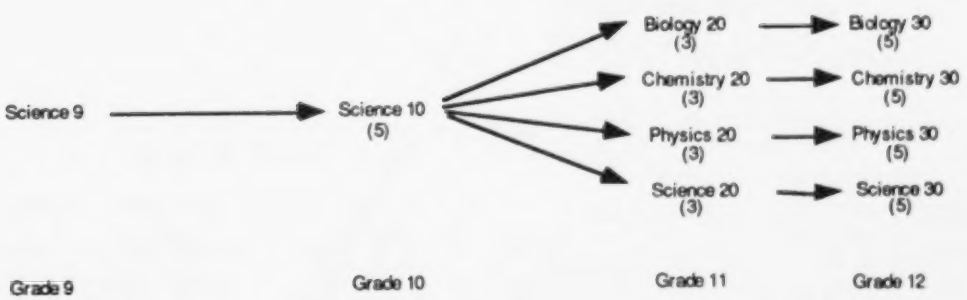

Figure 3. Proposed Program Structure for Academic Science Courses (Fall 1988)

During the 1988–1989 school year, Alberta Education seconded and contracted several teachers as program consultants to develop further the new programs. Hired as the program consultant for Chemistry 20–30, my task was to work with the external teacher committees to write specific learner expectations related to chemistry, based on the guidelines drafted in 1987. A chemistry teacher for the past 10 years, I had been working as a test-item writer for the student evaluation branch of Alberta Education. A new program manager was also named. With many more experienced, committed teachers working on the project, rapid progress was made, and by the spring of 1989, draft versions of programs of study for each of the senior-high science courses had been written and sent to schools for feedback.

In their responses, teachers paid less attention to the content of the programs and focused instead on the new structure and hours of instruction allotted for each of the discipline-specific science courses. They lamented that academically inclined students would receive fewer hours of instruction in a particular scientific discipline, resulting in less preparation for postsecondary studies. Under the structure in place at that time (Figure 4), students who chose a particular discipline to study in high school, for example biology, would receive 250 hours of instruction in Biology 10, Biology 20, and Biology 30; whereas under the proposed structure (Figure 3), they would receive 187.5 hours of instruction in Biology 20 and 30 , and a few more hours directly related to biology concepts within the 5 credits awarded for Science 10.

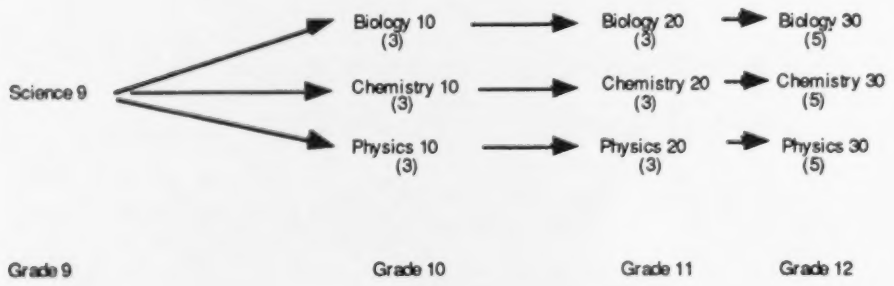

Figure 4. Previous Program Structure for Academic Science Courses (1977)

The ATA Science Council of 1990 disagreed with the 1988 position of the general ATA, publicly protesting this change, and later sent a questionnaire to teachers, the results of which, they claimed, supported their position. This discussion, related to the

program structure, overlooked the fact that students would be receiving *more* hours of instruction in science overall, for example, 315 hours for the combination of Science 10, Biology 20, and Biology 30.

Members of the scientific community responded negatively to the learner expectations, which many interpreted as emphasizing science-technology-society connections at the expense of basic science. In addition, they saw the introduction of the integrated program, Science 20-30, as possibly drawing students away from studying the individual scientific disciplines. It was obvious that they viewed this program as 'less rigorous'. Special committees were struck at postsecondary institutes and within professional organizations, such as the Association of Professional Engineers and Geologists of Alberta (APEGGA), in order to delve further into issues related to school science. The academic scientists assumed a leadership role in criticizing the changes in structure and content and formed an alliance with the academic high school science teachers. Soon, "it became clear that a defined hierarchy of status had emerged...[with] the highest status assumed by the academic scientists" (Panwar & Hoddinott, 1995, p. 508, 509). The focus remained on the third recommendation of the *Secondary Education in Alberta* document, that is; preparing students for work and postsecondary studies, while the first two recommendations regarding STS and responsible citizenship were largely ignored. A less vocal response was heard from the faculties of education and the humanities departments, for example the faculty of arts, at the universities, leaving the scientists to speak for what constituted good science education for high school students. The general public and media began to get involved in the debate at this time. Feature articles and letters to the editor began appearing in local newspapers and provincial magazines decrying the decline of science education in Alberta. As letters of protest arrived in large numbers at the office of the Minister of Education, members of the development team continued to uphold the original aims and objectives of this revision of science education—to improve scientific literacy through the incorporation of science, technology, and society connections with science concepts and to foster a student-centred, activity-based approach to learning that would motivate students to study science.

In mid-1989, the Minister of Education called together a group of leaders in science education and members of the scientific community to review the whole restructuring and revision process and to make recommendations for future directions. After studying a number of possible alternative scenarios, the committee recommended that

each of the senior high school courses should be offered for 5 credits (125 hours) as originally proposed (Figure 1), even if this would have ramifications for the timetabling of supplementary courses in Grade 11. They viewed science education as essential to the economic future of Alberta and advised it should be given a prominent status in the high school curriculum. They further advised that Biology, Chemistry, and Physics 20-30 should be developed as academically challenging courses that would prepare students thoroughly for future studies and careers in science. Development of the integrated academic program, Science 20-30, would also continue. "More and better science" was a phrase from this committee's report often quoted by the media. It is generally interpreted in the spirit of *Report 36* of the Science Council of Canada, meaning that one goal of education should be to increase the scientific literacy of all citizens, who will need more than ever to understand science and technology and their impact on society in the future. The Minister of Education advised curriculum developers at Alberta Education to seek advice from science educators and the larger community before continuing with the development process.

The Science Team, consisting of four program consultants and the program manager, embarked on a collaborative process to find out what science educators, professional groups, parents, and the community at large wanted to see included in the new Alberta science programs. The consultation process, which was unprecedented in curriculum revision, consisted of sending out questionnaires to as many stakeholders as could be identified and meeting with and speaking to interested groups and individuals at various locations in the province. Although the meetings proved exhausting for the curriculum developers, they were extremely useful in dispelling misapprehensions and providing a forum for discussing with those keenly interested in science education such questions as "what kind of science education does a young person need today?"

In 1989, the third major document to influence the development of the senior high school science programs in Alberta, the report of the American Association for the Advancement of Science (AAAS), *Project 2061: Science for All Americans*, was released. It focused on scientific literacy, viewed as embracing science, mathematics, and technology, as the central goal of education and described the scientifically literate person as someone who is the following:

- aware that science, mathematics, and technology are interdependent enterprises with strengths and limitations
- understands key concepts and principles of science

- is familiar with the natural world and recognizes both its diversity and unity
- uses scientific knowledge and scientific ways of thinking for individual and social purposes.

(AAAS, 1989, p. 4)

The statements in this report reaffirmed the vision for the new senior-high science courses developed at Alberta Education and provided a further rationale for the use of the fundamental concepts and key understandings of science as a framework for choosing and organizing the knowledge component.

The results of the questionnaires and face to face consultations had to be analyzed and melded into a comprehensive framework that reflected the vision and philosophy originally developed for the new programs. A recurring theme in the summary of the responses and consultations was students' need to know the basic concepts in science; which ones were basic, however, was the difficult question, given the explosion of knowledge in science. Support for science, technology, and society connections was weaker: the science had to come first, said most respondents. The results of the questionnaire and the face-to-face meetings showed clear and strong support for disciplinary science courses that would prepare students well for the next course and postsecondary studies. For many of the respondents the path to scientific literacy was through knowledge of science.

The Problem and the Questions

The intent of this study is to learn about the experiences of teachers implementing the new science programs and of the students in their classes. I also hope to reveal the perspectives of the participants involved in the curriculum development and implementation process and to compare the implementation experience of the teachers with the program's intent as seen by its developers. Some of the guiding questions are as follows:

(a) How do teachers approach the implementation of a new science program with an STS dimension, that is, how do they prepare themselves and what perspective do they bring? What effect does previous experience and education have on their approach?

(b) What is it like to be a teacher involved in the implementation of a science program with an STS dimension? How do teachers cope with the increased demand on their time, the uncertainty involved in an unfamiliar situation, and the natural human

tendency to resist a change that appears to be imposed from the outside or perhaps is not fully understood?

(c) How do teachers compare the new science program with the old one, in terms of teaching it? How do students react to it? Do teachers believe it is better for students? Is the intent of the program a positive development?

(d) How do teachers interpret the program of studies? What can a curriculum developer learn about writing curriculum from the experience of the teachers implementing it and the students' experience learning it ?

Careful attention to how teachers describe the world provides insights into how they construct it, and the language teachers use provides an image of their professional knowledge and the ways in which they represented it (National Science Teachers, 1994, p. 58).

The Nature of the Study

This study uses aspects of several orientations in an attempt to better understand the implementation process for Science 10. It is mainly a qualitative study that uses a situational interpretive inquiry method to understand a set of circumstances or events.

Aoki (1978) states that "In curriculum inquiry, there is an array of orientations that a researcher might adopt" (p. 7). The simplest is the "empirical analytic inquiry" in which "explanatory and technical knowledge in the form of facts is sought" and in which there are "ends-means" concerns. The inquiry is one of efficiency, effectiveness, and congruency between and among intended outcomes. States Aoki, "Within this framework, prized are empirical data and objective facts, free of values". The researcher with this technological orientation seeks rigour and quantitative data to be subjected to statistical analysis and describes the underlying interest of this research orientation to be within an "ethos of control". This orientation is a minor focus in this study. The data collected from questionnaires given to teachers and students were not analyzed rigorously to arrive at particular conclusions. The results were used to broaden the scope of the investigation and to provide support for statements made by others, thus increasing the validity through triangulation.

The "situational interpretive" orientation is a "search for meaning which people give in a situation" using the root activity of communication between people. The concerns of this researcher are what others think of the curriculum, whether they approve or disapprove, and what they perceive to be the program's strengths and weaknesses. In

Aoki's words, the "evaluators show interest in the meanings those living in the situation give to the curriculum experience" (1984, p. 9). Within the situational interpretive orientation, explaining requires striking a responsive chord among people in a dialogue situation, by clarifying motives, authentic experiences, and common meanings. The evaluator cannot stand aloof but must enter into dialogue with the people in the evaluation situation (Aoki, 1984, p. 10). Aoki states that "the situationally-interpretive oriented research is vitally complementary to empirical-analytic research and deserves close attention by curriculum researchers, particularly those whose interests lie in the study of curriculum-in-use" (Aoki, 1978, p. 12). This orientation is a major focus of this study. Face-to-face conversations with teachers involved in the implementation process provided the bulk of the data for this study.

The third orientation described by Aoki is "critical inquiry" in which the root activity is reflection and in which "normative knowledge" is sought. In this approach, the evaluator is interested in bringing into full view the underlying perspectives of programs that are normally taken for granted and hidden from view. Critical evaluators are interested in making the "root metaphors, deep-seated human interests, assumptions about man, world view and knowledge" more visible. To explain within critical knowing is to bring into fuller view underlying unreflected aspects (Aoki, 1984, p. 13, 14). This study moves partially into this orientation by looking critically at the development and implementation process for the Science 10 Course of Studies, and by identifying themes that underlie the implementation process.

A phenomenological study is one in which " the life world, the lived experience, is both the source and object of...research" (van Manen, 1990, p. 53). Merleau-Ponty describes phenomenology as "the study of essences", and van Manen expands on this, saying "A good description that constitutes the essence of something is construed so that the structure of a lived experience is revealed to us in such a fashion that we are now able to grasp the nature and significance of this experience in a hitherto unseen way" (1990, p. 39). He goes on to say "phenomenology asks...what is the nature of the phenomenon as meaningfully experienced?" (van Manen, 1990, p.40). This study asks the question: what is it like for a teacher to implement the new science program? Or rather, what is the lived experience of the teacher in this situation? The study concerns itself with "uncovering meaning". According to Werner "programs are interpreted and defined variously...on the basis of ...interests and background experiences" (1978, p. 13). He describes this kind of study as a "situational

interpretation" in which tasks are designed to make explicit the perceptions of various groups and the situational setting of a program, wherein "the focus is upon the multiple viewpoints which the participating actors use to interpret the program in their own unique situations." (Werner, 1978, p. 14, 15).

Although this study cannot be categorized as phenomenological, it contains some aspects of this orientation in that my personal involvement with the curriculum development process was very intimate. This involvement allowed me both the opportunities of a broad and a close-up view, as well as the luxury of time to reflect on purpose of science education and the implementation process.

Both the researcher and the participants come to a study with a particular perspective which is influenced by both personal and group culture. My orientation to this question is primarily that of someone intimately involved with the development of the curricular documents used by teachers, and that of a science educator who has also experienced the implementation of a new program in the classroom. As a program developer, I am also asking how the curricular documents, and perhaps the process by which they were developed, influence the teacher's experience in the classroom. Teachers, particularly if they have not had an extensive inservice or have not recently taken postgraduate courses in science education, may have quite a different notion of an integrated STS science program compared to curriculum developers. What is the relevance and meaning of the curricular changes to teachers as compared to what they mean to curriculum developers? The researcher oriented towards situational interpretive research must keep in mind the following:

- people give personal meanings to each situation experienced
- people interpret the same event in different ways.

(Aoki, 1978, p.11).

The researcher's job then is to make more clear and explicit the meaning of the interaction of teachers with the programs and to draw out for the reader the constructed meaning of the participants in the process. Therefore, the researcher must enter into dialogue with the participants in the research in order to draw out common meanings, and the interpretation must identify essential themes and provide explanations that are meaningful and seem right to the individuals in the research situation—and to the reader.

Research Methods

Proponents of qualitative research stress that "the most powerful way to understand humans is to watch, talk, listen and participate with them in their own natural settings" (Rist, 1982, p.440). For this study, four classroom teachers who are implementing the new Science 10 Course of Studies were asked to participate with the researcher in a qualitative, or naturalistic, study. Several data collection strategies were highlighted: observation, interview, questionnaire, and document analysis. The data for this study were collected through personal interviews with teachers, observations in their classrooms, and analysis of curricular and teacher-generated documents such as lesson plans and student assignments. The interactions with these teachers took place over one teaching term beginning in September, 1994.

In addition, a survey-type questionnaire was sent to 100 schools implementing Science 10 in order to obtain a broader sampling of teachers experiences and to provide some verification for the "rightness" of the themes and explanations that have been drawn from the in-depth human science research. Some of the results of this survey were available to me before my second conversation with the teachers and were used to guide the questions and discussion.

I also analyzed student questionnaires. During the Science 10 field test, students completed response forms in which they answered questions regarding the lessons and activities in each of the units of study. These experiences and observations and my analysis of the students' comments also form part of the data base that has become a part of the overall interpretations, themes and conclusions of this study. During the latter duration of the study, my oldest son was enrolled in Science 10. His personal experiences as related to me, as his parent, have also entered this discussion.

In addition the study consists of a literature review of other applicable and related studies and papers. Although teachers may have felt the structure of the science programs to be of greatest impact in the classroom, the most significant change that interested me was the inclusion of an STS dimension in Science 10 and the origin for this movement; therefore, I focused much of my library research on this area.

As a curriculum consultant for Alberta Education, I had a unique opportunity to observe and take part in the process that shaped the new senior high school science curriculum. During the course of the development of the senior high science programs, I visited

classrooms of teachers piloting Science 10 and interacted with many other teachers in various parts of the province during inservice and information sessions. I had many personal discussions with teachers, with my co–developers, and with others close to the situation. None of these conversations or observations were formally recorded, but they do form part of the rich experiences that were accorded me as I grappled with the meaning of the curriculum change, both as a curriculum developer and as a teacher who had personally experienced past curriculum changes. These internalized musings and subsequent insights I experienced also form part of this study.

Limitations of the Study

Qualitative research of a phenomenological nature asks the question, "What is going on here?", and focuses on ways of knowing that are based on experience, empathy, and involvement (Rist, 1982, p. 440). Such research takes a holistic, as opposed to atomistic, approach to understanding human behaviour, a situation, or event. Qualitative methods suspend judgment on what will be important, critical, or relevant. Therefore, there is neither a presumption that what is expected will be found nor an attempt to establish relationships between previously defined variables; instead, the focus is on finding out what is really happening. This study cannot give the answer to such questions as "has the science program been successfully implemented?"; such end-means questions only quantitative methods can attempt to answer. Instead, the strategy is to spend enough time in a situation with the people involved to allow the defining themes to emerge.

The study is naturalistic in that it takes place in a natural setting and does not attempt to control variables or manipulate the environment. The findings cannot be used to show that one method of implementation is more effective than another. Phenomenological questions ask about the meaning, or significance, of a situation, they are not problem questions to which a solution can be found. Meaning questions can be better or more deeply understood, so that, on the basis of this understanding we may be able to act more thoughtfully and more tactfully in certain situations. They provide insight for others, in a personal way, and can remain open indefinitely (van Manen, 1990, p. 23).

Qualitative data are a source of well-grounded, rich descriptions and explanations of processes occurring in logical contexts. Qualitative research relies strongly on description through the art of writing. For others to gain meaning and insight into the phenomenon studied, the researcher must be able to capture in appropriate words the

lived experience of others. The researcher must understand the nature of the lived experience, reflect on what has been learned, and make what is hidden or obscure more clear and obvious. Works, especially when organized into incidents or stories, have a concrete vivid meaningful flavor that often proves far more convincing to a reader—another researcher, a policy maker, a practitioner—than pages of numbers (Miles & Huberman, 1984, p. 15).

The bulk of data in qualitative studies makes it unlikely that more than a small sample of cases can be managed. Are the cases examined a reasonable sample of the whole? Put another way, what is the generalizability of qualitative findings? Van Manen recommends that one should not generalize from phenomenological studies, because this may prevent us from developing understandings that remain focused on the uniqueness of human experience (1990, p.22). The most serious and central difficulty in the use of qualitative data is that the methods of analysis are not well formulated. The analyst has very few guidelines for protection against self delusion, let alone the presentation of unreliable or invalid conclusions (Miles, 1979 in Miles & Huberman, 1984, p. 15, 16). Empirical research is often a matter of progressively lowering one's aspirations. One begins by wanting to study *all* (italics theirs) facets of an important problem or fascinating social phenomenon...it soon becomes clear that choices must be made (Miles & Huberman, 1984, p.36).

The first part of this study was limited to a small number of teachers over the relatively short period of time of one school term. The teachers and schools chosen were in close proximity to the researcher's home and were large urban and suburban schools in and around a large city. The number of interviews and visitations were limited to two to three per participant because of the demands of a full-time job and the "busyness" of the teachers. The questionnaires were sent to a sample of 100 schools offering Science 10 in scattered locations throughout the province, including small rural schools, but excluding adult upgrading facilities and private schools. Only teachers of Science 10 were contacted, even though all of the science programs have undergone revision. Approximately 600 student responses were reviewed. Although the duration of the study was approximately two years, I had worked intensely on the program of studies for almost five years; therefore, I feel I have an intimacy with the subject that goes beyond what appears on the surface.

Issues of Validity and Ethics

Gaining access, and the conditions under which it is granted, is one of the most critical phases of qualitative research (Rist, 1982, p. 442). Those who control access may seek to influence the research. Careful wording of the letter of introduction and the clear and direct answering of questions will be essential. If favours are asked in return, the researcher will have to exercise ethical judgment.

Gaining the trust and acceptance of those participating directly in the research can be a major hurdle. There may be tendency to mistrust a curriculum developer from Alberta Education and, either consciously or unconsciously, to withhold access or information because of anxiety or for fear of reprisal. Great care and thought went into explaining the study and the respective roles of the researcher and participants. Anonymity was absolutely guaranteed, and opportunities were provided for participants to add their comments and input into the analysis and interpretation of findings. (Appendix A contains copies of letters and permission forms sent to teachers).

"Qualitative researchers are primarily concerned with *process*... and in *meaning*—how people make sense of their lives, what they experience and how they interpret those experiences... (Merriam, 1988, p. 19). How can one be sure that one has interpreted another person's meaning correctly? Merriam (1988) defines internal validity as dealing with the "question of how one's findings match reality...Do the findings capture what is really there? Are investigators measuring what they think they are measuring?" (p. 166). She lists several strategies for ensuring internal validity including triangulation, member checks, long-term observation, and clarifying researcher bias (p. 169). This study also has empirical-analytical overtones in that it surveys a larger group of teachers implementing the Science 10 curriculum and provides an analysis of 600 student responses. The major purpose of this activity is to provide further validation for interpretations made on the basis of the case studies.

The interaction of several methods for collecting data—observation, interview, document analysis, and questionnaire—provide the validity check for this qualitative research. The multiple data collection strategies allowed the researcher to choose the most appropriate method for the individual situation. As Rist (1982) states, "the greater the alternative sources of data employed in the analysis of a setting, the greater the possibilities for accuracy and holistic presentation" (p. 444).

Significance of the Study

There is, at best, a tenuous connection between science education research and innovation in science teaching and learning. Feldman and Atkin (1993) suggest this may be "because there is not much research on science teachers or the dilemmas they identify as central to their work" (p.287). Curriculum change is ultimately about teacher development and change. Solutions must come through the development of *shared meaning* (Fullan, 1991, p. 7). The experience of the classroom teacher is fundamental to a better understanding of what constitutes the difficult task of implementing a new program. "Curriculum authorities who see their responsibility as promoting improvement in science education at a time of unprecedented change should develop a better understanding of the complexities of classroom life" (Roscoe, 1993, p. 16).

Failures in implementation have been more frequently documented than successes (Bragaw, 1992, p.4). Recent reform efforts have not been effective in allowing significant new ideas, pedagogies, or topics to be introduced into established school subjects What are the obstacles to change? Effective school research has indicated that establishing a climate for change is crucial to success, and that success can depend on the inherent level of imperativeness and mission, and an intellectual, inspiring, and democratic development process (Bragaw, 1992, p. 5). Analyzing how people experience change on a personal level can help identify some of the factors that are most significant to both the resistance to and the acceptance of change. Those who initiate the change pass through several stages that may include loss, doubt, rejection, discomfort, understanding and finally integration; but they have had the opportunity to do so as they plan the change. Therefore, the initiators of change sometimes have difficulty understanding why others cannot accept change more quickly. The innovators introduce changes without providing a means to identify and confront situational constraints, and without attempting to understand the values, ideas and experiences of those who are essential for implementing any changes...innovators need to be open to the realities of others; because the ideas of others will lead to alterations for the better in the direction of change (Fullan, 1982, p. 82, 83). The intensity of the qualitative research technique allows for a deeper understanding of the change process and can lead to new levels of self-awareness of how individuals adapt to change.

Educational change can be challenging, stressful, dynamic, sometimes frustrating, hard work, but it is ultimately rewarding. The teacher is the single most important component in the change process yet the culture of teaching may inhibit curriculum change. Teachers operate in a culture that fosters individualism and is classroom, rather

than community, centred. Senior high school teachers are particularly socialized towards loyalty to a specialized discipline of study stemming from the specialist nature of their undergraduate training and their success in that setting. Their identities may be shaped prior to any preservice teacher training or entrance into the teaching profession. Such a subject subculture is comfortable, and there is a natural reluctance to leave it.

The study is significant in that it can help the teachers involved and the readers of the report, who might be experiencing a similar curriculum change, to reflect on the process as they make the transition between old and new curricula. It attempts to inform us about what it is like to be a teacher and a student in a time of curriculum change in science—an "everyday lived experience" that most senior high school science teachers and students in this province have been involved in for the past several years. As we reflect on the changes to science education, it is natural to reflect on the purpose of science education. Recently the discussion has focused on scientific literacy—the understandings and abilities in science that students will require to function in their world. The processes of curriculum development and implementation provide the opportunity for educators to discuss these important questions.

Chapter Two

Literature Review

The following literature review traces the development of the STS movement in North America and describes investigations into the implementation of STS science programs in the classroom. It is meant to be neither comprehensive nor totally objective. As a curriculum consultant who worked on a science program with an STS dimension, I am convinced of the value of including STS contexts into science programs. As well, I believe integration of concepts from various scientific disciplines fosters higher level thinking and understanding of issues related to science.

Rationale for STS Science

The modern era of science education reform can be traced to the launching of the earth-orbiting satellite, *Sputnik,* by the Soviet Union in October 1957. This single event shook a nation in which debate had already been raging about what constituted good science education. Scientists had been critical of science education in the United States because it emphasized applied science (science for everyday life) over theoretical understanding (science for science's sake). Now here was "proof" that America was inferior in scientific knowledge compared to the what some thought of as a nation of peasants, the Soviet Union. After *Sputnik,* the US government substantially increased its financial support to the reform movement led by academic scientists and dedicated to making science education more rigorous and academic. "The National Foundation put scientists firmly in the saddle of curriculum reform, teachers were at best stable-hands, and education faculty rarely got as far as the stable door" (Matthews, 1994, p. 17). According to Bybee and DeBoer (1994), this emphasis resulted in a curriculum that emphasized the structure of the discipline and processes of science, because of pressure from the scientists who directed the curriculum projects, and the grave concerns of government leaders over the shortage of technically trained individuals in the industrial society of the time. They describe three significant changes in the goals of science education during the late 1950s and early 1960s:

(a) recognition of the personal-social developmental goal declined
(b) scientific knowledge was modified to emphasize understanding the structure of scientific disciplines and this goal became primary, especially at the secondary level
(c) scientific methods (inquiry, discovery, and problem solving) became a means of achieving the knowledge goal and not a means of solving society's problems.

(Bybee & DeBoer, 1994, p. 373)

This was the era of the 'alphabet curricula,' which still has a lingering effect on curriculum reform to this day. Projects, such as PSSC, CHEMS, and BSCS, largely ignored any practical or technological connections to science and focused on teaching theoretical science, with a passing nod to the nature of science . Academic scientists were in control of curriculum reform and continued to exert a strong influence for the next thirty years.

Paul DeHart Hurd was one of the first modern-day science education reformers to bring the focus back to scientific literacy. Defining it as an understanding of science and its applications to our social experience, he argued that science and its applications in technology had become a dominant force in our society and that it was difficult to discuss human values, political and economic problems, or educational objectives without consideration of the role played by science (Hurd, 1958, p. 336). He advocated the inclusion of such a dimension in science programs.

By the end of the 1960s, societal emphasis on science education had shifted from the "space race" to problems centering on the individual, the cities, the environment (Bybee & DeBoer, 1994, p. 375). In 1969, Paul DeHart Hurd addressed some of the issues of the reform movement of the 1960s in *New Directions in Teaching Secondary School Science*. Hurd pointed out that the reform movement had used scientists as the project directors and that its method of developing curriculum materials was structured by the question, "What does it take to provide an accurate picture of my discipline?" He stated that the discipline-centred approach to curriculum reform arose out of the passing of power to scientists in the 1950s and that the scientists' view of curriculum development is of a high school science as a mirror image of a scientific discipline. This view ignored the needs of the individual learner, assuming that the structure of the discipline would assist the learner to construct knowledge for her or himself. Only secondary consideration was given to the students' personal development and the community in which the student lived. Hurd (1969) went on to state, "We are in danger of educating youth for a world that no longer exists" and "seek to develop students with capabilities to cope with problems of a period not yet lived" (p. 10,24). Hurd questioned the emphasis on concepts of science in current programs asking, "the character of western civilization was formed by science and technology, but where is this reflected in the curriculum?" (p. 27).

The theme of scientific literacy gained additional prominence when the National Science Teachers Association identified it as the most important goal of science education in its position statement "School Science Education for the 70s". They recommended that the structure of the scientific disciplines and the processes of science be de-emphasized in favour of the themes of social relevance, student interest, the relationships between science and other areas of the curriculum, the interdependence of science and technology, and the human aspects of the scientific enterprise. The new goals of education should be to teach the aspects of science that would help students understand the world around them and to provide them with the tools for acquiring new scientific knowledge (Bybee & DeBoer, 1994, p. 377).

Bybee and DeBoer (1994) identify James Gallagher as one of the first persons to propose formally that science education be oriented around an STS theme in his 1971 article entitled "A Broader Base for Science Teaching". Gallagher argued that the curriculum projects of the 1960s took a limited view of science by focusing on the conceptual schemes and processes of science, and he stated that " for future citizens in a democracy, understanding the interrelationships of science, technology and society may be as important as understanding the concepts and processes of science" (Gallagher as cited in Bybee & DeBoer, 1994, p. 377).

Interest in reforming science education to include STS connections continued throughout the 1970s. Mary McConnell (1982) describes three studies undertaken by the National Science Foundation to determine the status of science education across the United States in the late 1970s: a literature review, a national survey of science educators, and a series of case studies. Project Synthesis, a two-year study of 'the countenance of science education', then made a number of recommendations based on the findings of these studies of science teaching. The major findings of the three national status studies were as follows:

- secondary school science teaching is textbook dominated
- little use of inquiry-oriented teaching strategies is evident
- the predominant instructional method is lecture-discussion
- secondary school science education lacks a sense of direction or a theory and philosophy to provide guidance for curriculum development and instruction
- emphasis is heavy on the pure 'structure of the discipline' form of science
- very little content in the courses provides information related to personal and societal problems, to technology, or to vocational relevance, except to those students interested in professional science careers

(McConnell, 1982, p. 2)

The survey results also showed a general antiscience tenor and public apathy toward science, declining enrollments in science courses, diminishing financial support, lack of leadership among science educators, poor quality in teacher education programs, inappropriate school science curricula, and a lack of a theoretical basis for education in the sciences.

The recommendations of Project Synthesis included the following:

(a)'A major redefinition and reformulation of goals for science education; a new rationale, a new focus, a new statement of purpose are needed.' These new goals must take into account that students today will soon be operating as adults in a society which is even more technologically oriented than at present; they will be participating as citizens in important science-related societal decisions.
(b)'A new conceptualization of the science curriculum to meet new goals and a redesign of courses is needed'. The redesigned curriculum will require STS materials for use in the classroom and preservice and inservice teacher education programs to develop teacher awareness of the importance of including STS as a legitimate subject matter for study.

(McConnell, 1982, p. 5, 6)

The research pointed clearly to a need for science education changes and at the same time raised a number of questions and dilemmas for leaders in science education about the feasibility of introducing the appropriate kinds of science, technology, and Society (STS) programs, that is:

- The cognitive complexity of issues under consideration as part of education about STS is formidable
- STS education is interdisciplinary in nature yet educational institutions at all levels have great difficulty operating outside of discipline-bound frames of reference.
- A great deal of understanding of science, technology, and society is necessary for persons to understand anything about them and their interrelationships.

(McConnell, 1982, p. 27, 28)

A paper by Faith M. Hickman (1982) provides further insight into the introduction of STS issues in the classroom at a time when the movement to include issues of science, technology, and society in science programs was gaining support. Hickman presents a summary of her 1981 study of 308 biology teachers to determine the science and society issues teachers choose or choose not to discuss in their classrooms, the amount of class time devoted to issues, and what prevents or encourages teachers to place a greater emphasis on science and society issues in the classroom. The study revealed that although the majority of teachers agree that it is important to bring issues into the classroom:

- teachers spent less time on discussing values than on scientific facts
- nearly a third of teachers rated major topics of biology more important than science and society issues
- more than half of the teachers indicated they have no time for issues of science and society
- barriers to teaching about science and society issues included difficulties with evaluation, lack of resources, and inadequate preservice and inservice opportunities

(Hickman, 1982, p. 364)

By the mid-1980s, many prominent educators (Yager, 1988; Bybee, 1987; Aikenhead, 1988) were suggesting that science programs must incorporate social issues and address the needs of all students, not just those planning to pursue further studies and careers in science. "Science education in the past has not helped prepare citizens for the life they will live. It has focused entirely upon preparing people for careers they will not follow" (Yager, 1983, p. 53).

Hofstein and Yager (1982) advocated a curriculum based on social issues, not on the organization of knowledge in the scientific disciplines, stating, "Rather than including information merely because it is basic to the discipline, the decisions should be made on the basis of relationships to real-life problems, thoughts and interpretations" (as cited in Bybee & DeBoer, 1994, p. 379). They argued that the discipline-centred curriculum projects that focused on an understanding of science for its own sake were motivating only a small segment of the society and that an issues approach would appeal to a much wider group of students.

In an attempt to find out how much attention was paid in the classroom to the connections between science content and its societal, reasoning and historical implications, Mitman et al. (1987) observed the classes of eleven seventh-grade life-science teachers. They concluded the following:

- teachers rarely or never addressed the noncontent components of science in instruction or assignments
- students perceived content as the prominent focus of instruction.

(as cited in Bybee, 1994, p.138)

A survey by Bybee and Mau (1989) evaluated the teaching of global problems related to science and technology by asking science educators about what they perceive to be the most important global problems related to science and technology, their knowledge of global problems, their estimation of public understanding of global problems, what

they know of what is being taught about global problems, and their recommendations for teaching about global problems. They were also asked to identify the educational trends and issues relative to global problems. The authors received completed surveys from 262 science educators representing 41 countries, an 80.6 percent response rate. Respondents were mostly male (75 percent), over 41 years of age (75 percent), and held a postsecondary degree in education (70 percent). Over half worked in a college or university, almost one-fifth were employed in research or curriculum development and approximately 8 percent were secondary level science teachers.

The important findings of this survey of science educators were as follows:

- they believed science and technology related global problems would be worse by the year 2000
- they were slightly or moderately knowledgeable about the problems, with print, audio-visual media, and personal experiences as their primary sources of information
- they felt it is important to study global problems in schools, that an integrated approach should be used, that courses including global problems should be required of all students, and that the emphasis should increase with age/grade level
- they reported that most countries are in the early stages of developing programs that include global problems and that there is increasing public support for this
- they identified the most significant limitations to implementation of the STS theme as political, personal, social, psychological, economic, pedagogical, and physical.

(Bybee & Mau, 1986, p. 618)

The results of this survey indicated general support for the teaching of global problems in science education, with implications for policy makers, curriculum developers, and teachers; for example:

- the vision, rationale, and goals for teaching within an STS (global issues) theme must be developed
- appropriate content, structure and practices for teaching about global problems within an STS context need to be identified
- programs and materials to address the goals of STS education need to be developed
- teacher education programs must prepare teachers for teaching about global issues in an STS theme.

STS Programs

Several fledgling programs using STS connections as curriculum organizers were developed in various parts of the world in the late 1980s and early 1990s. The following is a brief description of those with higher profiles and enrollments.

In the United States the most successful is *ChemCom*, developed with funding from the American Chemical Society in the United States, it focuses on selected chemistry concepts and their technological applications in the community. Students engage in cooperative problem solving and decision making to resolve hypothetical and real social issues posed in the textbook. *BioCom*, a similar program for the biological sciences, is currently being developed under a grant from the National Science Foundation. Both curricula have a strong science, technology, and society emphasis, a focus upon environmental issues, and a goal to encourage more students to sustain their interest in science and continue their studies of science until they graduate from high school (Leonard, Penick, & Speziale, 1996).

Several initiatives developed in Great Britain encouraged by the work of Joan Solomon. *Salters Chemistry* is an applications-led program developed by the University of York Science Education Group in Great Britain intended to make sciences studies more accessible to all students, while providing a sound basis for those who wished to pursue scientific studies to a higher level (Campbell et al., 1994). The *SATIS* (Science and Technology in Society) projects, sponsored by the British Teachers' Association for Science Education, arose from a concern that school science has been too academic and remote for many students, and so fails to prepare them for their adult and working lives. Generally, these programs consist of resource units for enriching science courses and have been well received by teachers in the United Kingdom (Hunt, 1988).

Most curricula in Canada have an STS component. Some of the programs with a major STS emphasis have a large enrollment because they are required by students for graduation, whereas other optional courses have limited enrollments. *Science and Technology (ST) 11* was developed in British Columbia for less-academic students who will not study science at a high level, with the raising of the scientific literacy of future citizens as its goal. A study of its effectiveness is included later in this chapter. LoRST, a program developed in Saskatchewan by Glen Aikenhead and taken by the majority of students entering high school science, uses controversies and dilemmas as a way of improving students' decision-making skills. *Science in Society* an integrated STS course developed in Ontario for Grade 13 students is accepted for university entrance, but has had low enrollments since its introduction in 1989.

In Alberta the concept of curriculum emphases, described as a set of implicit and explicit messages underlying the knowledge (Roberts, 1982), was used in the development of the Alberta Education *Junior High Science Program of Studies* (1989), a program taken by the majority of students in Grades 7 to 9. An investigation into this program is included in the next section. This concept of curriculum emphasis was not carried forward into the senior high school programs to allow for greater choice for teachers in choosing contexts for presenting the science topics. A detailed description of this approach is contained in Chapter 3.

STS in the Classroom

The movement toward a more socially relevant science program has not been universally endorsed or supported. Many science educators, and particularly scientists, object to the idea that science courses would be organized on the basis of contemporary social issues, instead of on scientific concepts. Although they did not object to the use of socially relevant problems to motivate students, they saw their use as curriculum organizers as part of a widespread flight from and watering down of science (Bybee and DeBoer, 1994, p. 379).

Many classroom studies are and have taken place to try to ascertain the value of introducing STS programs in the classroom. What have the many proponents of STS science programs found about the development and implementation of this approach to teaching science?

In the late 1980s, F. James Rutherford established Project 2061 at the American Association for the Advancement of Science (AAAS) in response to calls for the reform of scientific, mathematical, and technological education. The review process was very extensive and sought the advice of a large number and a diverse array of individuals, culminating in the publication of *Science for all Americans* (AAAS, 1989). The fact that academic scientists were the leaders of this reform movement is interesting; unlike the earlier reforms based on the structure of the science disciplines which resulted in the alphabet curricula, scientific literacy is the stated basis for restructuring the goals of science education in the AAAS movement. A major premise of Project 2061 is that schools do not need to teach more; they should teach less, so the content can be taught better. *Science for All Americans* suggests maintaining most of the topics currently common in school curricula. However, the treatment of topics should differ from traditional approaches in that the boundaries between traditional subject matter

categories should be softened and connections emphasized through the use of major common themes such as systems, evolution, cycles, and energy. Recommendations also include topics not common in school curricula: the nature of the scientific enterprise and how science, mathematics, and technology relate to one another and the social system in general as well as some knowledge of the history of science and technology. *Benchmarks for Science Literacy* published in 1993 as part of Phase II of Project 2061 states what *all* students should know or be able to do by Grades 2, 5, 8, and 12 and is a document intended to assist educators in designing curriculum that meets the standards for scientific literacy. As Project 2061 continues to develop into Phase III and more groups and individuals become involved in the goals, there will no doubt be a further influence on the science reform movement.

A study by Yager (1989) asked "how do students who have experienced science as a textbook-ordered consideration of concepts compare with students who have approached their study as a resolution of specific societal issues compare in terms of standard achievement measures, attitudes about science, and continued interest in learning about science outside of school?"

Yager compared two very similar groups of 26 students, using pretests and post-tests to determine student knowledge, achievement, and attitude. One test group followed the student outline and textbook and performed the activities described and recommended. The other group, although they also read the textbook, became involved in a local STS issue and spent "virtually no time" doing the suggested activities or discussing the textual material in class.

The author drew the following conclusions from the data:

- there were no significant differences on any of the pretests
- there were no differences for any of the content measures on the posttests
- students in the "issue oriented" section possessed a significantly higher positive attitude than students in the standard science course
- students in the "issue oriented" section were far more involved in their science studies outside of the classroom.

(Yager, 1989, p. 181)

The results of this investigation provide information that can be used to refute some of the fears and criticisms advanced by STS critics, that is, that students cannot learn basic science concepts as well in the nontraditional nontextbook-oriented classroom. A post-

test given one year afterward still found no significant difference in achievement between the two groups. The advantage suggested for the STS-oriented classroom is that the students will have more positive attitudes than students in the traditional classroom and that these students extend their learning beyond the school.

Yager et al. (1992) reported on a study of teachers in Iowa who were identified with a special interest in contrasting an STS focus with the more traditional one, for example. those interested in the development of creativity skills. The study involved 12 teachers of Grades 6 to 8. The study suggests that, when teachers express an interest and belief in student ability to achieve in particular domains of STS, the results are impressive.

The findings were as follows:

- STS students achieve just as well as students enrolled in more typical courses and outperform them in 25 percent of the classrooms
- STS students outperform non-STS students in their mastery of process skills
- attitude is three times better for STS students
- student creativity is improved in several domains in STS students
- the ability of students to utilize information and processes in new situations is three to four times greater for STS students compared to non-STS students.

(Yager, 1992, p. 30)

Yager (1993) reported that during the 1989–1990 school year, 15 lead teachers (teachers identified as having the richest experience with STS teaching and who also attended a two-week summer Leadership Conference) agreed to teach students between Grades 4 and 9 one section of science for an entire semester in an STS mode while also teaching a second section in a non-STS mode, that is, using a standard textbook and school curriculum guide as a source of concepts for teaching and learning. The same unit topics were used for both sections for a given teacher at the given grade level. The major difference between the two sections for a given teacher was the approach to instruction. The class sections were randomly designated, and there were no identifiable differences between the sections in terms of student ability, socioeconomic status, or interest. Both qualitative and quantitative methods were employed. A pre/post-test design was used and visitations were also made to the classrooms by the author.

The findings of this study were the following:

- the results of the pretest showed no significant differences between the scores of the non-STS and STS students in any of five domains identified by the authors.
- the two major findings of this study were that there was no difference in concept attainment between the two groups and that students in the STS group achieved substantially better results in all of the remaining four domains.
- high-ability students gained more than low-ability students in all domains, regardless of the instructional approach
- there was a significant gender difference in the attitude domain, with the STS females showing a positive change close to three times as large as the non-STS group
- older students in the STS group improved the most in applying science and technology concepts, whereas the younger students improved most in creativity and process skills.

(Yager, 1993 p. 80-81).

This study provides strong evidence for the potential of STS approaches for improving several domains that reflect commonly agreed upon goals of science education. It also suggests that it is best to introduce science process skills at a younger age (Grades 4 and 5), whereas science and technology concepts are better introduced to older students (Grades 8 and 9). It also identifies the potential of the STS approach to improve the attitude of young girls toward the study of science.

Because of the large sample size involved and the long-term nature of the investigation the results of this study are impressive even though, as the author points out, a group of very well-trained, experienced, and conscientious teachers were involved. The fact that the STS group made identical gains in concept mastery and significant gains in four other domains suggests that the STS approach used by an experienced teacher is successful.

A study that investigated the directions taken in the junior high science program in Alberta is described in the Ph.D thesis, *STS in the Classroom: An Interpretive Study* (Roscoe, 1993). This study sought to understand the interactions of teachers, students, and novel subject matter in the junior-high classroom. Roscoe describes three goals of the study as:

- to gain better understanding of the life world of teachers as they experience an STS curriculum change
- to inquire into alternative ways of conceptualizing STS curriculum implementation
- to critically analyze the STS curriculum.

(p. 6,7)

Roscoe reports undertaking this study partly because research indicates that planned changes rarely succeed as intended and that teaching practices are remarkably stable and resistant to change. He looked at the human and unique interactions between teachers and students in an STS context and the educational and moral implications of these interactions. He found that STS seems right for students, teachers, goals, and current situations because it stresses quality over quantity, positive experiences over efficiency. He believes that schools can become more educative, vital, and humane places through this approach. It is the interpretation and implementation of this "STS" program by two experienced, thoughtful teachers that Roscoe found most encouraging. He drew the following conclusions from the data:

- the teacher participants believe this new "STS" science program is right for students because it is less theoretical and abstract and more hands-on and relevant.
- integrating the sciences makes it more interesting for students and illustrates for them the many components of science.
- the program suggests a move away from the abstract, generalized knowledge of the established specialization to the more concrete and familiar.
- the science program is interesting to students because it is relevant to their lives.
- this "STS" course forces more interaction between the teacher and students and that is what makes it so motivating. Interaction is encouraged because there are issues that do not have a right or wrong answer. Discussion and conversation allow students to communicate and think about what they know, in the process creating and reshaping knowledge as they teach themselves and others.

(Roscoe, 1993, p. 178-182)

Even though these teachers were concerned about the role of standardized testing in relation to this approach to teaching, and were worried that the test makers did not share their beliefs in contextualized teaching with an emphasis on social relevancy, they strongly supported the program philosophy because of its positive effect on the attitudes of students. In his analysis of the junior high science program of studies, Roscoe concluded that the implicit statements about teaching overemphasized controlled experiments and the objectivity of science, at the students' expense of learning more about the world around them. The emphasis on educational outcomes is consistent with the production metaphor, and the bulk of content indicates academic concerns, such as preparation for the next course, and utilitarian concerns (centralized control of learning) ahead of pedagogical concerns (what is best for the learner). On the other hand, he found the Alberta junior-high science program of studies takes a constructivist view of

the learner and places student intellectual development ahead of knowledge for life, work, or further studies.

Science and Technology 11 (ST 11) is described as a course proposed in 1984 by the Ministry of Education in British Columbia to provide students with a better understanding of technology and science and their interaction with society. It was implemented in B.C. schools in 1986 and taught to 6,700 Grade 11 students, or 18 percent of the Grade 11 population. Zoller et al(1990) reported on a case study conducted in British Columbia schools to determine *ST 11* had any impact on students' views on issues related to science, technology, environment, and society (STES). For the study, a questionnaire consisting of four representative statements selected from the VOSTS[1] was administered to 473, 12th graders at six randomly selected public/comprehensive schools in the Greater Vancouver area during the first term of the school year 1987–88. The experimental group consisted of 101 students who had taken *ST 11* in the previous school year, and the control group consisted of 276 students from the same schools who had not taken *ST 11*. Specifically, they describe their objectives as follows:

- to assess the (possible) impact of *ST 11* on the viewpoints of senior high school students concerning the complex topic "science, technology and (Canadian) society."
- to assess whether and to what extent some or all of the prespecified, superordinate goals of *ST 11* have actually been attained in the first year of province wide implementation.
- to obtain a preliminary data base from the field, for possible future use in decision making and educational policy concerning STS courses and curricula.
- to evaluate some selected aspects involved in the implementation of *ST 11* under the particular constraints of British Columbia.

(Zoller et al, 1990, p. 22)

The authors concluded that a substantial change can occur in the viewpoints of students about STS topics through a course such as *ST 11*, and thus the attainment of the goals for the course is feasible; that their results are valid, transferable, and applicable to other STS and STES-oriented courses; and that the data base obtained will prove useful for future decision and policy making (Zoller et al, 1990, p. 34).

STS and Integrated Science

[1] VOSTS, which stands for Views on Science-Technology-Society, is an assessment instrument developed by Glen Aikenhead.

Leaders in the STS movement see a strong link between STS programs and interdisciplinary, or integrated, science. For example, Yager, in the Unesco Report, *New Trends in Integrated Science Teaching Volume VI* (1990), states that "STS is one reform effort which transcends a single discipline. STS is a major force in bringing traditional disciplines together" (as cited in Unesco, 1990, p. 44). Holman, in this same report, states that "STS is concerned with the application and issues of science in society. Taking such applications and issues as starting points is an effective way to integrate a science course. Such issues are by their nature interdisciplinary" (as cited in Unesco, 1990, p. 49). The rationale for teaching integrated science given by the Unesco (1990) document is as follows:

- The natural world is a unified whole and examining it through distinct disciplines can lead to a fragmented understanding of it.
- Students are interested in the real world about them and do not view it from the perspective of discrete disciplines.
- The major issues facing society today, such as disease, overpopulation and resource depletion, cannot be completely understood through one discipline of science.

The teaching of integrated science contributes towards general education, emphasizes the fundamental unity of science, and leads towards an understanding of the place of science in contemporary society. It avoids unnecessary repetitions and permits the introduction of intermediate disciplines (Chisman as cited in Unesco, 1990, p. 13).

Peter Chamberlain (1985) compared performance in A-level science examinations of students in a tertiary college who had taken the integrated science program called SCISP[2] with the performance of students who had studied the separate sciences to the O-level. Performance based on assessment was found not to be significantly different between the two groups, though SCISP students must have spent considerably less time per science subject.

The AAAS (1989, 1990, 1993) documents use the concept of themes, the large interconnecting ideas that tie together the disciplines, as links between the knowledge from the various science disciplines. These include systems, models, constancy, and change, and scale, which are described as "ideas that transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design" (Rutherford & Ahlgren, 1990, p. 155).

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[2] SCISP refers to the School Council Integrated Science Project (1973) developed in Great Britain and described as a transdisciplinary program that featured technological applications and social implications.

A number of initiatives have been undertaken in different parts of the world to incorporate themes into interdisciplinary science programs. These programs have met with mixed success at the high school level and are practically nonexistent at the postsecondary level. A major implementation of an integrated science programs with an STS dimension is now underway in Alberta. Six themes are identified in the programs of study for Alberta high school science: change, energy, equilibrium, diversity, matter, and systems. Their stated purpose is to unify the natural science disciplines. This study hopes to provide some insight into the implementation of this program. A similar set of themes is identified in other programs, including the Atlantic Provinces Science Curriculum Framework (1995), which suggests the themes of change, diversity, energy, equilibrium, matter, models, and systems as unifying ideas for topics in the life, earth, and physical sciences.

The viewing of science as a unified whole appears to be an international trend of increasing significance and impact. The Unesco (1990) report states that this approach, if carefully planned, has the potential of improving the scientific literacy of all students (Unesco, 1990, p. 132). What do studies into integrated STS science programs have to say? According to a Unesco study into such programs, schools that have taught students in an integrated manner produce the following results:

- an increase in the elective enrollment in science
- a great proportion of students choosing science as a major at college
- grades as good as or better then their peers who have studied separate disciplines
- higher scores on science literacy tests.

(Unesco, 1990, p. 132)

Again and again the trials of integrated courses in various parts of the world have confirmed the lack of enthusiasm of teachers teaching outside their usual scientific discipline (Hahmed as cited in Unesco, 1990, p. 97). Hacker and Rowe (1985) report on a study of specialist teachers delivering an integrated science curriculum. Informational approaches were found to be more likely when the teachers were outside their specialist discipline, the change being at the expense of problem solving or inquiry. These findings cast doubt on recommendations that unification would best be achieved by a single teacher because science teachers do not share the developers' enthusiasm for teaching outside specialist areas.

The Unesco report on integrated science identifies the following as key issues in the attempts to bring integrated science into the classroom:

- nonacceptance of integrated science as a university option
- training teachers for confidence in teaching integrated science

(Unesco, 1990, p. 88)

In 1994, the science curricula for middle school was revamped in Texas to present science using a thematic approach. Instead of offering life science in Grade 7, earth science in Grade 8, biology in Grade 9, and physical science in Grade 10, students would complete, by the end of year 4, one year in each of biology, chemistry, physics, and earth/space science through the integrated approach of the Coordinated Thematic Science Program. It is hoped that this new program will dramatically improve the level of scientific literacy among students in Texas.

In this study Crawley and Salyer (1995) tried to identify the beliefs of four Grade 7 life science teachers in order to study their intentions in introducing physical science activities and also to investigate the origins of the beliefs. Most of the secondary science teachers in Texas have specialized training in one scientific field and lesser training in other fields, particularly the physical sciences. Among the questions posed by the researchers were the following:

- What are the encouragements, constraints, ideas, and outcomes that might apply to new reform initiatives?
- What is the nature of the support system that is necessary for sustaining reform?
- Are there common impediments and constraints to change?

(Crawley & Salyer, 1995, p. 613)

The researchers define beliefs as the "teachers' preconceptions and implicit theories" that they use to "make decisions and guide their behaviour". In this qualitative study interviews, questionnaires, and journals were used to delve into "teacher attitude, social support and perceived behavioural control that underlie teachers' intention and identify the origins of their perceptions and beliefs about curricular implementation" (Crawley & Salyer, 1995, p. 613).

Based on the information provided by the four teachers in this study, the authors developed several assertions about school science curriculum reform for this situation. In summary, they are as follows:

- teachers are motivated to take part in a retraining program if they have an expectation of improved student learning and interest in science through the implementation of the new integrated program. Themes associated with favorable outcomes of integration included improved student understanding of science, increased student interest in science, and enhanced student understanding of the everyday world and the varied content provided.
- implementation of the Coordinated Thematic Science Program created in some teachers a need for communication and coordination with other science teachers
- some middle-school teachers view their high school colleagues' lack of support for the new program as a potential a barrier to implementation. Other barriers include lack of time, materials, and equipment, inadequate training in physical science, and lack of support from administrators
- teachers rely on their experience as teacher and student to form their beliefs about the value of the new science program
- articulating beliefs about the new coordinated science program may bolster teachers' commitment to it.

As others have also said, Crawley and Salyer (1995) state that "the ultimate success of curriculum reform...rests upon how the reform is implemented in the classroom...and moving from the rhetoric of reform to the reality of change in the classroom is a complex task"(p. 612). The researchers also conclude that the teachers are willing to take on a new belief system if they think it is better for their students. They state that "Teachers' beliefs are...central to the process of curriculum implementation" (p. 613). What may need to be considered beyond the teachers' belief systems are some of the other milieus that may impinge on the implementation of the curriculum such as the context in which the teacher is working as well as the larger community in which the classroom resides.

The new curriculum herein described breaks down the structure of the disciplines of biology, chemistry, physics, and earth sciences. These have a long tradition in the academic community and this restructuring is likely to receive resistance from this group. Possibly, this resistance might be coming down through the high school teachers identified by the middle-school teachers in this study as a possible impediment to the implementation of the integrated science program. The teachers described are certainly a product of this structure of science, and it may be quite difficult to break through their paradigm of the structure of science. The study concludes that teachers rely on their experience as teachers and as students to form their beliefs. How does the community shape their beliefs?

Crawley and Salyer (1995) state, "The road to reform is a lonely one"(p. 632). They felt that teachers' professional development during the reform process would be enhanced by frequent conversations with their colleagues at all grade levels. The implication is that administrators need to provide time and structures for communication between science teachers, which may require a breakdown of current structures and ways of doing things. Administrators could arrange the timetable so that science teachers had a common preparation time, and principals from neighbouring schools could encourage interlocking professional development days. Helping teachers obtain the materials and other resources they need to implement the program would be another way administrators could facilitate the introduction of this curriculum. Naturally, administrators also have to believe that this is a better program for students before they can be co-opted into the process.

The need to reflect on curriculum reform is identified in this study as important in changing teacher belief systems. Participation in inservice sessions is a key factor in promoting acceptance of curriculum reform, largely because there are opportunities for interaction between teachers with a common interest. Inservice usually falls to the policymakers and is of course a costly undertaking. As a result of the study the authors felt that they better understood the importance of teachers' voices, the importance attached to personal practical knowledge, and the need for teachers to have an opportunity to reflect on the process of science curriculum reform (Crawley & Salyer, 1995, p. 631).

Teachers and Curriculum Change

Tobin, Tippins, and Hook (1994) carried out an interpretive investigation into a science curriculum change and one teacher's beliefs. In the introduction to their report, they state that a 20-year history of research into classrooms "suggests that traditional practices in science classrooms have not changed appreciatively in that time, and that classrooms in various parts of the world are more alike then they are different" (Tobin et al., 1994, p. 245). A teacher named Karl, who was the main subject of this study, by his own admission maintained teacher-centred lessons, but desired to give students more control over their learning and the curriculum. An analysis of observations of his classroom and artifacts collected from his class indicated that he taught science with an emphasis on "learning content and rules to get correct answers". His personal

reflections on his discomfort with this approach indicate, however, that he had no referent for an alternative guide for action. He states:

> .. one part of me is saying they (students) should be sitting there listening and ...should learn what I think is important...the other side of me is saying they should learn what they think is important...there's the conflict. and I don't have a picture of the classroom the way I want it to be because I don't think there are any classrooms like that, or I'm not aware of it...so beliefs don't play into action.
>
> (Tobin et al., 1994, p. 252)

Later, when this teacher had an opportunity to work with and observe another teacher who allowed his students much more freedom in the classroom—one who basically said to his students, "here's your stuff, go learn what you want to learn." Karl was able to construct a vision of what was happening and how he could adapt it to his own circumstances. In the end though, Karl could not put his beliefs fully into action because of a variety of sociocultural factors that operate in schools. The authors concluded from this study that constraints such as shortage of time and the beliefs of fellow teachers as well as students, favoured the retention of traditional practices.

Teachers are the most important factor in the implementation of any new and innovative program such as STS science. Michener and Anderson (1989) identified five themes common to the perceptions of 14 secondary science teachers about the implementation of a model STS program:

- concerns over there being sufficient science content
- discomfort over grouping students for STS activities
- uncertainty about how to evaluate STS outcomes
- concern about providing college-bound students with what they need
- confusion about the teacher's role, that is, how does a science teacher teach about social issues?

(Mitchener & Anderson as cited in Bybee, 1994, p. 139)

These findings reinforce the key role of teachers in any curriculum reform process and the need for a support structure assisting teachers to deal with the day-to-day questions that arise during planning and instruction.

Chapter Three

Analysis of the Science 10 Course of Studies

The following section describes the vision, rationale, and philosophy of the Science 10 program and includes a brief outline of the content. A comparison of Science 10 with the previous Grade 10 science program provides an opportunity to address the question of what has changed.

Vision Statement

The vision statement for Alberta's Science 10 course of studies and each of the other senior high school science programs clearly states that there are two major goals for the senior high school science programs: to "help all students attain the scientific awareness to function as effective members of society... and to pursue further studies and careers in science". The dual goals of scientific literacy and preparation for the next level of study in science can be in opposition, and indeed, this dichotomy has led to some discomfort for teachers and administrators, as I will discuss later. This tension is particularly true of Science 10. Once students complete this program, they can enroll either in specialized discipline programs in biology, chemistry, or physics, in the integrated academic program, Science 20-30, or in the nonacademic program, Science 14-24. Students who enroll in the discipline courses are viewed by teachers and administrators as serious students who may eventually pursue postsecondary studies in science. In fact, only a small minority will, but to serve them, the second goal of the senior-high programs takes precedence in these courses. In the Science 20-30 program, the first goal of scientific literacy is given at least equal status because these students are not seen as planning on further studies and careers in science; therefore, the need for scientific literacy is equally important. The low enrollments in this program gives some indication of the value that is placed on this goal. Within Science 10 there tends to be competition between the two major goals. Which teachers choose to emphasize depends partly on their personal philosophy and largely on the sociocultural context of their school and community. In most cases the parents of academically inclined children speak loudly in favour of preparation for a broad range of postsecondary studies. This leads to pressure on teachers of Science 10 to focus on this goal, regardless of their philosophy, and on administrators and counselors to encourage all students to enroll in the subsequent discipline courses instead of in the integrated program, Science 20-30.

In the vision page of each program of studies, it is also stated that "students will focus on learning the big interconnecting ideas and principles of science...major themes... that transcend and unify the natural science disciplines" (Alberta Education, 1995a, p.1). Clearly, the aim is to foster integration of the science disciplines through the unifying concepts of change, diversity, energy, equilibrium, matter, and systems. These are prominent in the titles, overviews and major concepts for each unit, a prominence that strongly suggests that this an integrated science program. However the message of integration and unity among the science disciplines is not so clear in the specific learner expectations, most of which can be identified as belonging to either the biological, chemical, or physical science. Only Unit 1 clearly brings together concepts from several disciplines. The student textbook, *Visions 1*, customized and developed for Science 10 by Gage Educational Publishing, fails to integrate the concepts from the disciplines to any extent. This tendency is perhaps a pitfall of the process of custom-development of resources. The publisher, overly anxious to adhere to the requirements of the contract, followed the specific learner expectations point by point, losing sight of the vision for the program. The writers chosen for this project were also largely educated in a pure scientific discipline and could not be expected, nor were they likely asked, to write in an integrative manner.

The process by which the learner expectations were developed may also have resulted in separation, rather than integration, of the disciplines. The teachers on the committees and the curriculum consultants who worked with them also had specific discipline training and experience, so they naturally wanted to ensure that the basic principles from biology, chemistry, and physics were well represented. Similar groups working on the development of the pure discipline courses also had an influence on Science 10. They wanted to ensure that the students entering these courses from Science 10 had a good grounding in each of biology, chemistry, and physics. As mentioned previously, the other stakeholders within the power structure were the postsecondary scientists, and they too favoured a strong disciplined science base for students coming into their institutions from high school. Therefore, the two components of Science 10 that teachers would use the most to plan daily lessons, the specific learner expectations in the program of studies and the basic textbook, are not strong models for the integrated science promised in the vision, the philosophy and rationale, and the general learner expectations. This, along with the previously mentioned pressure on teachers to prepare students for the next discipline-based course, has led to the situation in some schools where Science 10 is viewed as three "minicourses" in the disciplines of biology,

chemistry, and physics, with little integration between them. The learner expectations in the first unit, related to meteorology and the unifying concept of energy transfer are often given minor attention.

Can teachers, without a thorough understanding of the unifying ideas and steeped in a discipline-based tradition, be expected to provide explicit emphasis in their lessons of the interconnectedness of science? Suggestions for integration using themes are delineated in the Teachers Resource Manual and examples were provided in inservice workshops provided by Alberta Education, but the latter were not available to all teachers in the province and many teachers have told Alberta Education that they generally do not make a great effort to study the Teachers Resource Manual due to lack of time.[3]

An additional objective stated in the Science 10 course of studies is to help students "understand the nature of science and the relationship of science to technology and to society". Science 10 is a science program with an STS dimension in which students are "expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationships among science, technology and society" (Alberta Education, 1995a, p. 5). It is suggested that this goal is to be accomplished using contexts chosen from the STS connections listed with each unit, or by choosing "any other relevant context". Therefore, the STS context chosen can be entirely up to the individual teacher to decide. Most proponents of STS programs recommend that contexts be largely student driven, and that option is encouraged in Science 10. The downfall of such an open-ended approach is the lack of understanding of the various dimensions of STS by both teachers and students. Most teachers mention (technological) applications first when asked about connections to science. Few feel prepared to address value-laden or emotional science, technology, and societal issues, and very few believe that the history of the development of scientific knowledge is a relevant context for high school students. Teachers' most recent experience of science courses is in discipline-based studies at university where it would be quite unusual if any of these dimensions of STS had been addressed. It is well known that science programs at the postsecondary level also can drive what occurs in the Science 10 classroom. If the teacher feels obligated to prepare students for eventual study of

[3] Based on teleconference held with teachers during the field test of Science 10.

science at the university level, where there is little support for social issues in science, then the STS dimension will likely be given less attention.

Several sources describe the changes in classroom practice suggested by an STS, integrated approach to science (Bybee, 1987; Yager, 1995; BSCS, 1993), based on the premises of constructivism. Yager (1995) states that STS programs require teaching techniques that "help students formulate meaning for themselves", by encouraging students to do the following:

- identify questions and problems that they see as important
- invent or plan activities
- express their views, discuss, and take action on them
- prepare products that result from learning activities that can illustrate student "expertness" as a result of lessons (rather than giving a test of memory as a closure activity to lessons and instructional units)
- take actions and displays outside of school to create a feeling of importance for the study, for example, community improvement projects.

(Yager, 1995, p. 227)

Accordingly, he describes the STS classroom as follows:

- student centred and directed by students' questions and experiences
- individualized and personalized approaches that recognize student diversity
- using a variety of resources
- valuing cooperative work on problems and issues
- planned around problems and current issues

(Yager, 1993, p. 77)

The Biological Sciences Curriculum Study describes an instructional model based on a learning cycle with the following five stages:

(a) engagement
(b) exploration
(c) explanation
(d) elaboration
(e) evaluation.

Teachers acting consistently with this model would, at the beginning of a lesson or topic, create interest and curiosity and uncover what students already know about the concepts. In the second stage, teachers would encourage group work and provide students with time to work through problems as they observed and acted as consultants. They would encourage students to explain in their own words and ask for justification and clarification from students while formally providing definitions and

explanations. In the later stages, the teacher would expect students to use the definitions and explanations previously provided while encouraging them to apply and extend their knowledge to new situations. Evaluation would involve teacher observations that look for evidence of changes in student behaviour and thinking, self-assessment by students, and open-ended questions (BSCS, 1993).

Beyond a change in content and organization, the curriculum for Science 10 suggests a drastic shift in pedagogy. In the Philosophy and Rationale for the program is implied a constructivist viewpoint within the statement: "Learning is facilitated by relating the study of science to what the learners already know", and students "will take varying amounts of time to acquire...science learnings" (Alberta Education, 1995a, p.1). An inquiry method for learning is emphasized. For example, it is stated that: "students will further their ability to ask questions, investigate and experiment; gather, analyze and assess scientific information; and test scientific principles and their applications" (Alberta Education, 1995a, p.1). Students are described as "active learners" who "will assume increased responsibility for their learning" (Alberta Education, 1995a, p.1). In the vision, there are also several statements that emphasize the fostering in students of positive attitudes to learning science and the importance of relevance to student learning.

The changes in pedagogy implied by this recent science curriculum change may be the most difficult to accomplish in the context of school and societal cultures that favour retention of classroom control in the hands of the teacher, as well as the valuing of facts over knowledge, and the emphasis on standardized multiple-choice examinations. Instruction in the traditional classroom is most often directed by the textbook, which is usually the exclusive resource. The level of instruction is geared to the average student who is seen as a recipient of instruction; the assumption made that students learn best when material is presented by organized, step-by step information. This approach in which knowledge is "predigested" for students takes the wonder out of science and discourages an inquiry approach to science learning.

Program Rationale and Philosophy

Many of the vision statements are reemphasized in the program rationale and philosophy: for example, there are references to "scientific awareness essential for all citizens in...society", "key concepts and principles", " unified view of sciences... and the connections among them", " methods of inquiry", "positive attitudes", "relevant

contexts", and "increased responsibility for...learning" (Alberta Education, 1995a, p.1). In addition, the philosophy and rationale emphasize other goals not specifically mentioned in the vision: here it is stated that students are to "exercise their creativity and develop their critical thinking skills;" the program is "to provide students with opportunities for acquiring knowledge, skills and attitudes that contribute to personal development" and "help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities" (Alberta Education, 1995a, p.2). These statements tie this particular program to the larger goals of basic education related to personal development and citizenship.

In the introduction to the specific learner expectations for all the senior high science programs, including Science 10-20-30 and Biology, Chemistry a Physics 20-30, is an explicit message about the preferred teaching strategy in the form of the learning cycle. This description is intended as a guideline for incorporating the STS connections into lesson planning. Programs of study are narrowly defined by Alberta Education as comprehensive listings of what students are expected to know and be able to do at the completion of a course. The accompanying teachers resource manuals describe appropriate pedagogical approaches. The two together replace the curriculum guides, previously produced for all Alberta programs. Developers, wanting to emphasize this particular teaching strategy decided to describe it in the program of studies, which teachers read very closely,[4].

Organization of the Course of Studies

The learner expectations for Science 10 are arranged into four categories: attitudes, knowledge, skills, and STS connections, whereas the course of studies consists of two major sections. In the general learner expectations section are listed the program expectations which are common to all the senior high school science courses intended for academic students. The program expectations for knowledge define each of the scientific themes to be developed: change, diversity, energy, equilibrium, matter, and systems; and describe how these "transcend the discipline boundaries, and show unity among the natural sciences". The program expectations for skills outline a comprehensive framework of skills that can be applied in a variety of problem-solving

[4] Based on personal conversations held with teachers who often referred to the program of studies as "their bible".

contexts. These skills are organized into several categories: "initiating and planning", "collecting and recording," "organizing and communicating", "analyzing", "connecting, synthesizing, and integrating", and "evaluating the process or outcomes" (Alberta Education, 1995a, p.4, 5). The program expectations for STS connections identify eight dimensions encompassing the nature of science, the nature of technology, the interrelationships between science and technology, and the interrelationships among science, technology, and society. The listing of program general learner expectations is linear and consecutive, but in the course's general learner expectations, the various categories of learnings, that is, knowledge, skills, and STS connections, are brought together into summary expectations for Science 10. In the section of the course called specific learner expectations, unity is provided among the categories through the way they are displayed across the page. Each category of learner expectation is formatted as a column and the four columns are placed next to one another across two facing pages.

Left Hand page *Right Hand Page*

Major Concept	Knowledge	Skills	STS Connections

Figure 5. Format of the Science 10 Course of Studies (1995)

This format allows the expectations to be read either from left to right or right to left across the pages. Read from the left, the major concepts and themes are the focus, and the skills and STS connections are simply associated with, and supportive of, them. Read from the right-hand side, the STS connections become the focus, particularly because of the summary statement that appears at the top off this column in which the expectation is that the knowledge and skills on the left are to be addressed *within the context of* the STS connections listed. This statement and format makes the Alberta programs unique among mainstream science programs from other jurisdictions, because of this focus on using science, technology, and society connections as organizers for instruction and learning.

There are four units of study in Science 10, each with a major emphasis on the science themes chosen as conceptual foundations for the senior high school science programs.

In Unit 1, "Energy from the Sun", students investigate how radiant energy from the sun sustains life on Earth and the significant role of water plays in this and many other energy-transfer processes. The specific learner expectations for knowledge, skills, and STS connections are arranged across the page such that the reader can see at the glance how each component supports the others.

Table 1 Sample Components of the Specific Learner Expectations for Science 10

MAJOR CONCEPT	KNOWLEDGE	SKILLS	STS CONNECTIONS
1. Energy from the Sun sustains life on Earth.	*Students should be able to:* • define photosynthesis as the process by which green plants (producers) put together carbon dioxide and water to store energy and form carbohydrates and oxygen	*Students should be able to:* • perform an experiment to demonstrate the role of light energy in the he production of carbohydrates and oxygen by green plants	*Students should be able to* • trace the energy contained in a typical student lunch to its source in the Sun, using the laws of thermo-dynamics

(Alberta Education, 1995a, p. 12)

Quickly one can see the laboratory activity and the STS activity that students will do to better understand and see the relevance of the knowledge statement. Each specific learner expectation can also be traced back to a general statement in the front part of the document, resulting in a consistent message throughout the document. For example, the section above is derived from the following general learner expectation:

> describe how energy and matter are transferred in all physical and biochemical changes; and identify energy transfers in the hydrologic cycle, photosynthesis and respiration, the combustion of fuels, and energy conversion devices
>
> (Alberta Education, 1995a, p. 6)

In Unit 2, "Energy and Matter in Living Systems", students investigate how energy and matter are exchanged between living systems and their environment. In Unit 3, "Energy and Matter in Chemical Change", students investigate chemical change from the perspective of energy and matter changes. Unit 4, "Change and Energy", further investigates energy changes in physical systems, describing the changes quantitatively.

Comparison of Science 10 to the Previous Program

In times of transition, those charged with implementing the changes inevitably make comparisons with what preceded those changes. From the point of view of a program developer for the new science curriculum and a teacher of the old science programs, I would like to provide my comparison of the previous and current science programs for Grade 10 students. An in-depth comparison is also given by Blades (1994) in his unpublished thesis, *Power and Possibilities for Change in Science Education Curriculum -Discourse* , so I would like to bring his point of view into the discussion. In other parts of this account, I shall report on this comparison from the point of view of the teachers who were part of this study.

As mentioned previously, the initial change in structure proposed for the Grade 10 academic science program was drastic and not well received by teachers and the scientific community. Within the previous structure students entering high school could take up to three half-credit courses in biology, physics, and chemistry for a total of 187.5 hours of instruction. Therefore, in large high schools teachers could concentrate on one discipline, teaching for example only Biology 10-20-30. The traditional pecking order also existed among the disciplines, with physics teachers assuming the top perch. With the new structure all academic students take Science 10 for 125 hours of instruction. Discipline-specific teachers now had to learn concepts from the other disciplines and define themselves differently.

When comparing the general objectives and goals for Science 10 with those for Biology 10, Chemistry 10, and Physics 10, one finds many similarities. Both make statements that support the broad goals of scientific literacy, particularly those related to STS science. For example, consider the following statements:

- "to develop an understanding of the interrelationships of biology and technology, and their influence on society" (Alberta Education, *Biology 10-20-30 Curriculum Guide*, 1984, p.17)

- "to develop an awareness and critical understanding for decision-making on value issues arising out of the use and misuse of chemistry" (Alberta Education, *Chemistry 10-20-30 Curriculum Guide*, 1977, p.4)
- "to develop an interest in physics as a natural science, an appreciation for improving natural knowledge and an understanding of the impact of its technological development" (Alberta Education, *Physics 10-20-30 Curriculum Guide*, 1977, p.7)

A major difference between the old and new programs is the relationship of the front part of the document (general expectations) to the later sections (specific expectations). Of the STS statements made in the general objectives for the previous programs, only the one related to the historical contexts for science knowledge is again mentioned in the core learnings. This was strongest for Physics 10, as illustrated by statements such as "the works and teachings of Aristotle formed the basis of ancient science" (Alberta Education, *Physics 10-20-30 Curriculum Guide*, 1977, p. 10). The intention in the previous programs was that other aspects of STS would be addressed in the elective units, but within the reality of the classroom, few if any of the elective topics were ever taught[5]. The amount of material in the core units probably precluded this or teachers did not feel confident enough to address topics related to the nature of technology and the environmental issues, given the paucity of resources available. Therefore, these aspects of STS were never addressed to the extent suggested by the general goals and objectives for the programs.

The STS monograph, *Unifying the Goals of Science Education*, (Alberta Education, 1994) describes STS programs as taking the step of merging the front matter of programs of study and curriculum guides, where the philosophical statements regarding STS objectives are listed with the specific learner expectations for students. "This integration of STS components is the main challenge to teachers presenting a curriculum that tries to meet all the objectives of science education." (Alberta Education, *STS Science Education*, 1990, p. 4). In the Science 10 course, similar statements in the general learner expectations are supported by specific learner expectations. Although the choices provided in the STS connections column can result in an uneven emphasis on particular aspects of STS, it is still clear that this is an important dimension of the program. The question remains though, are teachers today any better prepared or motivated to address STS given their traditional background and the lack of support for such topics from academic stakeholders?

[5] Based on personal experience teaching Biology 10 and Chemistry 10 in large high schools.

Interestingly, the general objectives for the previous programs were written in outcomes-based language, whereas the core objectives were listed as concepts; yet it is the latter that were followed most closely. Typical language used in the core objectives was as follows:

- "Multicellular organisms illustrate such levels of organization as tissues, organs and systems" (Alberta Education, *Biology 10-20-30 Curriculum Guide*, 1984, p.32)

- "Matter is classified on the basis of physical and chemical properties" (Alberta Education, *Chemistry 10-20-30 Curriculum Guide*, 1977, p.20)

- "A study of motion must take into consideration the importance of direction" (Alberta Education, *Physics 10-20-30 Curriculum Guide*, 1977, p.19)

In Science 10, the program general learner expectations provide a framework for the course learner expectations, which describe the essential attitudes, knowledge, skills, and STS connections for each course. The course general learner expectations for Science 10 clearly indicate that this is an integrated program and that themes play a prominent role in providing the unity among the concepts chosen from the disciplines of biology, chemistry, physics, and earth science and that an STS focus will be present. This is illustrated by the following course expectations:

- describe how energy and matter are transferred in all physical and biochemical changes; and identify energy transfers in the hydrologic cycle, photosynthesis and respiration, the combustion of fuels, and energy conversion devices
- apply the law of energy conservation to energy transfer, calculating efficiency; and identify ways of conserving energy
- use the relationships among force, distance, work, energy, and time to describe how energy is measured; and compare the functioning of common energy conversion devices
- apply the principle of conservation of matter to calculations and investigations into chemical changes that produce substances useful to society and/or may have unpredictable effects on the environment.

(Alberta Education, *Science 10 Course of Studies* , 1995a, p.6)

After his exhaustive investigation into the recent development of the science programs in Alberta, Blades (1994) concludes "that the final program of studies for Science 10 represents, with the possible exception of Unit 1, an amalgam of topics from Biology 10, Chemistry 10 and Physics 10" (Blades, 1994, p.81) and that *"the attempt at change in science education in Alberta must be considered overall a failure*" (Blades, 1994,

p.82, italics his). I would argue that the hope expressed by Blades that the new senior high science programs would be integrative of the sciences and have an STS approach has been realized, albeit to a limited extent. I believe that he made this pronouncement on the basis of a document alone, whereas the experience of a curriculum in the classroom is much more complex involving the interaction of the personal knowledge of teacher and students and the resources brought to assist with learning. This investigation and my personal relationships with teachers, as well as events that are occurring in various parts of Canada and the world, provide the encouragement that teachers and others have taken seriously the scope of the changes and that they are having an effect in classrooms in Alberta and on curriculum development in other jurisdictions.

Chapter Four

The Interviews

In May of 1994, I applied to the superintendents of two school districts in and around a major city to involve several teachers in this study. They were very agreeable, asking only that I share the results of the investigation with them. I then contacted the principals of the schools involved to seek their permission to work with several teachers with whom I had had some prior discussions about my study. In June of 1994, I contacted the teachers to seek their final agreement regarding their participation. Two of the teachers changed their minds about taking part in the study when they heard that so few teachers were to be involved; their concern was that the in-depth nature of the study would make it difficult to ensure their anonymity. Another teacher was concerned about the time required, having just taken on a new assignment, and so also declined. I was able to identify two other teachers willing to participate. In the fall of 1994, I received consent forms and a completed questionnaire (Appendix A) from four teachers who became the subjects of my study over the 1994-95 school term. For the purposes of this description, I shall call them Ann, Beth, Colin, and Dan.

Teachers and Setting

Ann is a young teacher with several years of experience teaching junior high school science and mathematics and who recently moved to a high school environment. Very energetic, she has an excellent reputation as a hard-working and innovative teacher. She has her B.Sc. and B.Ed. degrees, was working on a masters degree in education, and doing a project on performance assessment at the time of the study. She is also very busy with out of school activities. Recently married, she has no major family responsibilities and so puts most of her effort into teaching and personal study. She is teaching at a medium-sized school on the outskirts of a large city with an enrollment of 850 students, most of whom are bussed into the school, sees about 110 students a day, and teaches biology and nonacademic science in addition to Science 10. The science department in her school consists of four men and four women with an average age of 37. Her school is well equipped in terms of laboratory equipment, computers, and library facilities.

Ann reported that the individuals who have had a particular influence on her science teaching include teachers she had while in grade school, a cooperating teacher who

mentored her while she as completing her practicum assignment, and an instructor while she was at university. She finds that the teachers she works with and the teachers she has met while attending masters classes at the university are now sources of inspiration and ideas. For personal reasons, Ann had to leave the study midway.

Beth is also a young teacher with about six years of teaching experience. She has completed a B.Sc. and a master's degree in education. There are a variety of experiences in Beth's background. She has taught at several schools in and around a large city and worked for several agencies: she has participated in a teacher work experience program for the Alberta Research Council, worked for Environment Canada, and has presented workshops for the Alberta Teachers Association Science Council. As a single person, she devotes most of her energy to teaching and extracurricular activities at her school and is very close to her parents. She has also provided input on several learning and teaching resources and has a special interest in promoting gender equity in the classroom.

Beth teaches biology and integrated sciences, including Science 10, to 110 students. She is at a fairly large metropolitan school with an enrollment of 1100 students and 120 teachers on staff. The students come from a working class community with a multi-ethnic makeup. Teaching with Beth in the science department are nine full-time science teachers and two teachers from other departments who teach one science course each. The school is relatively well equipped, although starting to show wear because of age, and Beth finds the rooms too small for the large class sizes that have become the norm in recent years.

Beth reported that she was greatly influenced by a teacher she had in junior high school who helped her overcome an aversion to mathematics and by colleagues she has worked with over the years because of their great subject-area knowledge and "hands on" approach to teaching science. The field work she did for Environment Canada caused her to realize the importance of field trips and "active science" for students.

Colin is an experienced teacher with many years of academic training and teaching experience. He is the science department head of a large inner city school with an enrollment of approximately 2000 students. The science department consists of 19 teachers. The surrounding community is largely middle class but the school draws students from all parts of the city. Colin has taught high school chemistry and physics

for 28 years. During the study, he was teaching the International Baccalaureate program in chemistry and integrated science, regular chemistry, and Science 10 to approximately 120 students. The school is well equipped for teaching science with spacious laboratories and combination lab/classrooms.

Colin's accomplishments in the field of science education are many. He served on a committee that developed the previous high school science curriculum in Alberta, authored several books and papers, and served on the Alberta Teachers Association Science Council. He has presented papers and workshops at numerous conferences, many of them international. He is also involved in several extracurricular activities. Colin's children are of university age so his responsibilities are fewer than they were previously when his children were avidly involved in many activities. Now, his mother is quite elderly and needs more of his attention.

Colin reported that his views on teaching were particularly influenced by his high school chemistry, social studies, and biology teachers and by two professors at university, one with a major in physical science and the other with a major in social studies. Social studies was the minor subject of specialization for his undergraduate degree, and an interest in social studies also played a role in his Ph.D. studies. The report of the Science Council of Canada influenced Colin's views of STS in science education, as did his own readings on the nature of science.

Dan is about 40 years of age and comes from a varied background of experiences. He has taught special education classes for many years as well as secondary science, had a career in the Canadian Armed Forces, and worked for the Canadian Wildlife Service. He taught secondary science in Africa from 1987 to 1989. He has degrees in science and education and at the time of this study was working to complete a Ph.D. in education where his special interest was in how students perceive science.

Dan teaches in a large high school (population 1150) in a bedroom community of a large city. The majority of the students' parents work at white collar jobs in the city, and there is much less ethnic diversity compared to the city schools. The school is modern and well maintained and equipped. There are nine teachers in the science department, two-thirds male. Dan worked part-time at the school and studied half the day at the university for the duration of the study; Dan taught biology and integrated science, including Science 10, to about 100 students. Dan reported that two teachers in

junior high school and high school and two professors he met at university had a particular influence on his teaching.

Conversations and Class Visitations

I visited each of the classrooms of the subject teachers one or two times during the duration of the study. In each case, I arranged a time that gave the teacher plenty of notice and was agreeable to him or her. In the classroom, I tried to be as unobtrusive as possible, sitting at the back, taking notes as the students came in, and observing quietly from my seat or walking around and speaking to students as they performed activities. Most students seemed hardly to notice that I was there, only a few asked who I was. Every student I asked said that they liked Science 10.

I had two conversations of between 40 to 60 minutes with each of the teachers, except Ann who had to leave the study after one conversation. One conversation with each participant took place near the beginning of the school term and the other near the end. Each conversation was taped and transcribed word for word and returned to the teacher for further input. (Sample transcripts appear in Appendix B). Guiding questions were used to initiate the conversations, but often the interchange went, as conversations tend to do, in unexpected directions.

Ann's Class

Ann bounced into the classroom enthusiastically. The combined laboratory-classroom was so spacious that she seemed small in it, and there seemed to be fewer than the 23 students present. Everything was in its place, and there were colorful posters and bulletin boards on the walls. After a brief introduction by Ann, the students went to work at stations Ann had set up with the help of the school's lab aide. Ann was teaching all of Unit 3 of Science 10, "Matter and Energy in Chemical Change," by having the students work in groups of two or three to complete activities requiring varying amounts of cognitive effort. Some of the activities simply involved the students reading portions of the textbook and defining terms and answering exercise questions, whereas another required students to perform a risk-benefit analysis of a technology of their choice. At other stations, the equipment and materials for chemical change reactions were displayed, and students were to follow instructions from the textbook or at the station to carry out the experiment, make observations, and draw conclusions. Some of the more interesting and colourful reactions Ann had found in the journals and newsletters she reads regularly such as the NSTA Newsletter. Some of the independent

inquiry activities required that students use creative abilities to produce either a poster, brochure, short story, or video to convey information. Another activity required students to view a video about how plastics are made and used, and to answer questions. At each station, there was a debriefing section in which students were instructed to describe the most important concepts they had learned somewhat like keeping a journal. In addition, the activities had been structured to accommodate differing student abilities, by providing alternative activities for more and less academically inclined students. At the conclusion of the unit, students were to put together a portfolio of the work they had done worth 40 percent of their unit mark.

It was obvious that Ann had put a great deal of thought and effort into designing the teaching unit and had a strong belief in students' abilities to learn independently and in small groups. She made herself available for help while the students worked on the activities, and occasionally, she would provide lessons on particular topics, upon request. When I spoke to Ann sometime later, she told me that all the Science 10 teachers in her school had adopted this performance-based approach to teaching Unit 3.

From the way Ann had structured this unit, it was obvious she believes in the vision and the philosophy and rationale of the Science 10 program, that is, that learning should be student-centred, that students should take more responsibility for their learning with the teacher as their guide, that there be a focus on the inquiry processes of science and the ways in which scientific knowledge develops, and that students learn by doing science.

Conversation with Ann

Ann , for the duration of time she was in the study, taught an advanced Science 10 class. The previous year, she had taught a regular class, and in our conversation, I asked her to make some references to this experience with Science 10 as well. Ann was using Science 10 to try out a variety of teaching strategies that would help her attain the goals for the course. She was using several different approaches to incorporating STS and was assessing students with a variety of techniques including multiple choice, extended response, and performance tasks. She described her summative assessment for Science 10 as follows:

> We had the traditional part of the test (multiple choice and short answer questions), then the ...STS part of the exam. They had to go through seven different chemical compounds and tie in environmental aspects and tie in biology, and then had the skills. We had stations set up...I had a schedule on

> the board where ...six students per twenty minute period just get up... and do the skills. I would go over and mark it as they were performing (with a checklist), and then I'd have a five minute period to ...set everything up for the next group.

She described how she incorporated STS connections into the daily routine by putting the onus on the students to bring in articles and describe the science, technology, and societal issues related to it and its relationship to the course content. They also had to be prepared to answer questions from the class. Ann said that she encourages students to look beyond articles that are obviously about science topics and choose items for which they must do some thinking to see the science connection. She finds that in preparing this minilesson, students often go beyond the science that is in the Science 10 course of studies, but she is not concerned, because in their subsequent studies, they will have to learn these concepts, and she prefers not to dampen the enthusiasm of her students .

Ann expends a fair amount of effort in helping her students make the transition from junior high school to high school, identifying their background weaknesses and adjusting her teaching style accordingly. She finds that even students who have achieved a good mark in Grade 9 Science may be lacking in areas related to the identification of problem statements, variables, and carrying out experiments independently.

Ann credits her emphasis on interactive, "hands on" science for how well her students are prepared for the next grade level in science. Although students may have forgotten the knowledge lessons, they remember the concepts learned through activities. These are Ann's words on this topic: "If you're in a rush and ...just show ... this video or provide... these notes, but ... not do a lab.... You can see it two weeks later on the unit test." Ann believes that Science 10 prepares students well for making decisions about issues that arise in the community because it provides them with well-rounded background knowledge of several sciences and an opportunity to discuss issues. In her words:

> I think they're just more aware. They can understand their political issues... a lot of politicians are on the science bandwagon and know they are going to get votes... It (Science 10) provides them with a good background. I think you need basic physics and chemistry (as well as biology).

With a background in biological science, Ann needed to learn concepts in physical science to prepare for teaching Science 10. When asked how she did this, Ann replied,

"I just went out and asked for help. I feel that after six years of university, I can probably learn grade 10 level physics. It just takes a little time, that's all." In her department at school, there are frequent meetings and divisions of labour for preparing lesson outlines on the various topics. Ann has become the expert on performance-based assessment among her colleagues.

For Ann, the greatest advantage to a science program, such as Science 10, is the opportunity to integrate concepts from the various units of study through the use of themes. In fact she expressed the opinion that some individual topics in the course, for example, weather and water, do not work as well independently as when they are tied to other topics through the themes of matter and energy. She believes that integration helps students to learn. In her words, she says:

> ...our world isn't strictly one thing. So, in fact, that (integration)...makes more sense to them. They can relate to it. You relate it to something that they're aware of and they can, in their minds, say 'Oh yeah, I can see how that's connected. Okay,...I'll buy into this.'

Ann also believes that an integrated science program allows for a more thorough understanding of a topic. Once students have learned some chemistry concepts (she prefers to start with Unit 3, "Matter and Energy in Chemical Change"), she can then bring these concepts into a study in the area of biology, for example, photosynthesis. However, she feels the greatest advantage comes in studying issues, such as the environmental effects of a pollutant, when concepts from various disciplines can inform the discussion. Lastly, integration allows Ann to complete the course in plenty of time, despite a large concept load.

Ann is very positive about teaching Science 10, because it coincides with her beliefs about what a good science program should be. The three major ways in which Science 10 differs from past science programs offered to students in Grade 10 – an emphasis on independent hands-on learning, the STS dimension, and the integration of several science disciplines through the use of themes–coincide with Ann's philosophy about teaching science.

Beth's Class

When I arrived to visit Beth's class, she sent a student to the office to bring me to her classroom, because it was important for her to be there when her 30 plus students entered the room. The combined laboratory-classroom was almost too small for the

large number of students, and I felt pushed into the corner. The students had to sit very close to one another. The room was neat and tidy and nicely decorated with posters and other wall coverings. Beth explained that even though it was not her home room, she felt it was important to make it attractive, colourful, and personalized.

Beth was teaching a lesson on weather from Unit 1 of Science 10 and had prepared an extensive hand-out of terms and brief explanations to accompany the textual material. Although her teaching style was basically didactic and teacher-centred, it was also very interactive with her students. She asked many questions and encouraged her students to ask questions and make comments. To compensate for her inability to have students do many individual activities, Beth did frequent demonstrations to illustrate science concepts.

Beth's belief in the importance of STS to science teaching was very obvious in the lesson. She continually talked about connections that made the science lesson relevant to the students, brought in newspaper articles, and talked about the weather network on television. This raised many questions in the students' minds about phenomena that they had observed or heard about, and many interesting side-streams to the main lesson developed. For example, when Beth demonstrated, then explained, convection currents, students asked about the source of heat waves. The topic of atmosphere on the earth and other planets led to an animated discussion of pressurized suits, travel to other planets, pressurized cabins on air planes, scuba diving, the bends, and decompression chambers. Beth encouraged questions and discussions. A student naturally made a connection to a social studies topic she had studied recently.

Beth believes strongly in making science relevant for students and welcomes the STS connections in the Science 10 program of studies. She told me that she had always brought relevance to her teaching. Her only concern now is knowing enough to answer the questions that arise, because she is teaching out of her field of expertise (biology). When there arises a question to which Beth does not know the answer, she promises to find out for the next class. Like many teachers, she takes a great deal of the responsibility for her students' learning preparing extensive supplementary notes for topics not well addressed in the basic resource.

Beth told me that, even though she strongly believes in a "hands-on"" approach to science teaching, it was very difficult to conduct experiments under the conditions in

this room. She feared for the student's safety and as there was not an adjacent supply room, equipment and materials had to be brought in on trolleys from some distance away. Beth also described the challenge of keeping this group of students settled and attentive because of several individuals who tended to disrupt the class with loud comments and side-talking to others. During the duration of my visit, Beth had to frequently speak to individuals to remind them of the task at hand, but overall, she was able to keep the interest of the majority of students and complete the lesson as planned. I could see that this was emotionally and physically tiring for her. Revising her style of teaching to a more student-directed hands-on approach Beth sees as too risky, given the circumstances of the group of students and the room she was assigned.

Conversation with Beth

Beth was teaching Science 10 for the first time, so I was interested in her reactions to the course as she became more familiar with it over the length of our relationship. This was also the first time in four years that she had taught Grade 10 students, and she found herself amazed initially at how different they were from her older students. She explains, "I couldn't believe how full of beans they were. Teaching Grade 11s and 12s you forget what they're like, especially in September, when they're new from junior high....I had to lean on them a lot. They're really active."

The other aspect that Beth found different in teaching Science 10 was the mixed abilities of the students. Many students were not prepared for the academic rigor of the program and were struggling, while others were showing signs of boredom. Others were not well prepared from junior high school. Beth wondered if she should have started out with conceptually difficult topics in order to "encourage" some of the weaker students to enroll in Science 14, a less-demanding science course for Grade 10 students. Beth views herself as responsible for the success of her students and was determined to help them achieve, irregardless of their learning difficulties or knowledge/skill deficiencies. She explained how she works with the students who need extra help:

> I've had help session after help session with them...daily after school. I had ten of them until 4:30. They really appreciate the help sessions. They're also not very good at doing homework. The help sessions enable them, but they're not working on it too much themselves. Their parents had to sign it (their last test) and get it back to me, so they know that they have a unit exam next week and have to study and do homework in science every night.

The first time teaching Science 10, Beth felt constantly rushed to complete the requirements of the program and regretted not being able to do justice to an aspect of

the program that she most fervently believes in: a focus on activities. For example, she told me:

> I think a part of their science education is to learn to manipulate equipment, to heighten their skills of observation, to understand scientific methods....If we don't do a lab, its terrible...well that's what science is. Sometimes though, they do get sacrificed because of the sheer knowledge volume we have to go through.

The amount of content in the Science 10 program has been an issue with many teachers, and Beth referred to this as well:

> We're a little behind . We should be moving into the next unit right now, and we're just finishing off matter, energy, and chemical change. I wish they hadn't put so much content in . I wish they would have let us play a little more. These are only Grade 10s. There are a lot of concepts they need to know. I wish we could focus more on the STS.... time, it feels like such a luxury that's just not there in this course.

The pressure of preparing her students for the next course in the sequence weighed heavily on Beth, as she expressed in one of our conversations:

> I've heard the comment, 'what Science 10 class is that student from, who taught them Science 10'. You realize there's a lot of pressure, especially in a big department. We're told, for example: 'You make sure those kids that come out of the chemistry unit know that stuff.' I don't know if the next level teachers are willing to lower their expectations. You don't want to let them (the students) down for when they're moving on.

Beth expressed how she feels responsible for her students and is constantly questioning her approach in order to help her students learn. On the other hand, Beth finds that the attitude of the students to be a factor in their learning; she said:

> I do feel responsible. If they do poorly on an exam, it's very seldom I'll put the blame on them. They don't have a strong work ethic, so sometimes the only way to get them to understand is to be there. They were supposed to do some of the weather unit on their own, and very few of them did. They just don't do much homework. I do feel responsible, and it's because of their lousy work ethic, I guess. ...it worries me a lot...I'm really thinking...How could I change things.

STS connections seemed to be the most natural aspect of Science 10 for Beth to incorporate into her lessons because she had been doing this ever since she began teaching. For her students, the relevance of any learning must be demonstrated, and "scientifically literate" is more than just jargon in her vocabulary.

> It's critical to me—the STS term, we used to call it relevance...it has to be relevant. It's very important for kids, otherwise it's so horrid to keep their interest and to keep them motivated in class. I think they should come out of

> high school being really literate in science, so they have a good grasp of everything that's happening with technology ...and around them.

Beth provided some examples of how she incorporated STS into her lessons:

> I try to bring in as many concrete examples as I can. When we're talking about endothermic, we'd bring in athletic heat pads and cold packs. Make sure I say rust, not just oxide. So they know that these chemicals are out on the street, not just something that's in a lab. Sodium bicarbonate—I talked about stomach acid and how the pancreas secretes it. I would tape some of the weather forecasts and put them on, and we analyzed what was happening.

I asked Beth about her success in integrating the scientific disciplines in Science 10 through themes. She replied for herself and her colleagues:

> We try, but probably don't teach by theme as well as we should. We still get caught up in the subject... the biology section, the chemistry section...we've got a mindset of the units (of study) being quite separate disciplines. But having this first unit: Energy from the Sun', and themes in the titles of the other units helps a lot. I have to struggle to be consistent with those themes when I'm in my little subject-area specialty. Also, (when feeling the pressure of preparing students for the next course) I feel totally like a discipline teacher.

Beth, as a teacher with a specific discipline expertise, struggled with preparing herself to teach in the other science areas. She expressed it this way:

> I feel a little inadequate, because for me to come up with neat examples...you have to feel pretty strong in your discipline. Sometimes you wish you had more at your fingertips. I'm quite envious of people who have multidisciplinary backgrounds. I know I'm going to be sitting down and bashing it out myself. Yes, it's a case of studying. It's ongoing. I feel like a first year teacher.

Beth did note that teaching an integrated science program changed the relationships within the science department of her school: "It's created a lot of dialogue between colleagues. They're very good at helping. Just try to catch them. They're very busy."

Beth told me she believes that Science 10 is a good program for kids because it gives them a background in several areas of science they would not likely have had with the previous discipline courses offered in Grade 10. She said, "I like them to have a taste of everything before they go on." This, coupled with the integration of STS connections, prepared students for the many issues and problems they would face in the real world. From the perspective of the teacher though, Beth found Science 10 difficult to teach, particularly to find a focus because of the sheer amount of material and the tremendous possibilities for STS connections and depth within any one scientific discipline. As the teacher she had to work hard to navigate through the richness of this program. As she became more familiar with the science content in each

of the units it was easier for her to judge the appropriate depth and scope. What is most distressing to her is not being able to take an activities-based approach, a limitation which she attributes to her particular teaching situation coupled with the amount of material to cover in the program. She feels that teaching Science 10 on a semestered schedule might be beneficial for students because of the daily contact and the opportunity to build on concepts with some momentum.[6]

Colin's Class

Colin had told me to drop into his class at any time, even without phoning ahead. When I arrived he welcomed me warmly. The combined laboratory-classroom contained bench-style tables, and approximately 25 students sat on stools. The room had many posters, books, sets of equipment stored here and there, and had overall a slightly untidy and busy look. On the side white board were written reminders of upcoming due dates for assignments and tests.

As Colin prepared to teach, many students were busily checking answers to the homework assignment with one another. The first activity involved individual students going to the front board and writing down their answers. Meanwhile, Colin went over the objectives for that class.

The first half of the class time was taken up in going over homework, and this time was used as an opportunity to clarify any misconceptions, review past learning as well as bring in extra information on the history of science and the applications of concepts. For example, Colin spent some time talking about historical figures, such as Lavoisier, Dalton, and Mendeleev, and how they added to our knowledge base in chemistry. He was very careful to use terminology correctly and provide basic, correct knowledge as building blocks for future learning.

Students were encouraged to ask questions and also to volunteer answers to questions. This discussion was dominated by several students and may have discouraged others from thinking through the question or volunteering an answer. These students were very knowledgeable and had obviously learned a great deal about chemical reactions.

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[6] Many teachers in the field test had the opposite view, stating that younger students need sufficient time to digest the volume of material and see the connections between concepts form various science disciplines. Some schools are now trying the Copernican system where students concentrate on only two courses over a 12-week period.

For the second half of the class, the students went to a nearby laboratory to do an activity. Ten stations had been set up around the room by the lab aide and students were to use the chemicals at each station to cause some reaction to occur, then make observations of evidence for a chemical change. This half went smoothly, although the students reported feeling rushed to complete the task and had some difficulty in deciding what to record.

During the next class, the main activity was to discuss the previous day's lab activity. Colin once again used this as an opportunity to talk to students about how scientific knowledge develops, making reference to replication and controls, ambiguous results, and how scientists settle disputes. He reminded them of the difference between observations and interpretations. The original problem of evidence for chemical change lead to some discussions about changes of state.

In the latter part of the class, Colin reminded students of the date of the upcoming term examination on the "physics" and "chemistry" sections of the course, going over what topics are to be covered. The students would have a different teacher for the "biology" units.

It is evident from the observation of his class that Colin considers the inculcation of good work habits in his students as one of his most important tasks. Taking up homework is an activity that occurs at the beginning of each class, and students are frequently reminded of upcoming assignments and assessments. The other aspect of Colin's class that stands out is the significance he places on the "nature of science" dimension of the STS connections, while other dimensions of STS are given less attention. Colin told me that he incorporates technological applications of science concepts where there is a natural opportunity, but does not feel that students in Science 10 have the knowledge or maturity, nor is there the time, to discuss related STS issues. He feels students are ready to identify perspectives on an issue, but not to do an in-depth investigation. Colin believes in preparing students well for the next level of science courses they are taking and told me he is proud of the large percentage of students in his school who successfully complete discipline sciences to the Grade-12 level.

Conversation with Colin

Colin told me that his first experience teaching Science 10 was not positive. His lack of a strong background in the life sciences integrated in Science 10, particularly his poor knowledge of biology, led to a variety of problems. He says:

> People like myself who started off teaching the biology section hadn't had any biology since high school. The kids knew more biology than I knew from their junior-high science. I think a lot of the flow disappeared, and as soon as (that) happens, up pops the ugly head of those two or three students... who want to disrupt that particular class. I would have a limited time to read (to find appropriate contexts) if I'm going to pick up on the biology concepts.

Several of the other teachers in his school were having similar problems so they sat down together to propose a solution. The solution was that the Science 10 program would be taught to each class of students by two teachers. A teacher with a background in biology would teach Units 1 and 2, and a teacher with a background in the physical sciences would teach Units 3 and 4 to the same group of students. Two of the teachers in the school, one with a background in teaching junior-high science, opted to teach the entire course themselves. Colin explains the reasoning behind the decision to use a 'division of labour' approach to teaching Science 10:

> ...it wasn't just the trouble we were havingwith the content, but also the parental complaints. Also...we had very experienced teachers who were used to doing STS and weren't comfortable just teaching content. They could go home and learn the content for the next day, but felt very uncomfortable about the fact they couldn't relate it to the regular world; they couldn't bring in the STS issues. The pedagogy has to count as well. Students are go[illegible]o learn better from somebody who has some experience teaching it. At the end of the year... a lot of people said, 'yes, I can see the merit in integrated science, but I would rather have STS science' They saw more of the focus of the original curriculum reform in the province as being STS than integrated science.

Looking back on the experience of this approach, Colin deems it successful: parental complaints are not an issue anymore, discipline problems have been alleviated, and the atmosphere in the classroom changed when teachers had confidence in terms of content. He hopes that sometime in the future he and other teachers will feel confident enough to carry the entire Science 10 course, especially when packages of learning materials to supplement the textbook are available. Colin blames shortfalls in the basic resource for Science 10 for some of the initial problems:

> If the textbook had been strong in terms of providing the pedagogic assistance students need.. a split might never have occurred. There was insufficient practice in the textbook. It... took the orientation of activity, activity, activity. We felt that there was going to be insufficient time to do all those activities and cover the content that was required. We saw the textbook as inadequate to provide practice exercises, so we were scrambling to provide those ourselves,

> and we felt that each of the discipline teachers could perhaps put together exercise packages to supplement the textbook. Outside the disciplines, we couldn't make those kind of judgments. Teachers inside their disciplines could evaluate the course in terms of what to cover, what not to cover, what labs to do, and what kind of extra materials would be needed. After that, any teacher should be able to, if circumstances work out, move within two years into teaching the entire course.

Although Colin admits that this approach taken in his school does not facilitate integration of concepts between all of the scientific disciplines, he believes that by agreement among the teachers to use common approaches, for example, in writing up laboratory reports, the students see less of a dichotomy from teacher to teacher.

The attitudes, maturity, background knowledge, and work habits of students must be considered in any approach to teaching Science 10; for Colin, as for the other teachers in this study, there are pedagogical implications. Colin is meeting, in Science 10, a heterogeneous group of learners with varying levels of maturity and background. Only 10 percent of the incoming Grade 10 students in his school enter the nonacademic science stream. He says:

> Getting Grade 10s to pay attention, and to learn and learn how to learn is something we keep coming back to in Science 10 over and over again. ...that has been more difficult than previously with Chemistry 10, Physics 10, Biology 10. It's a more heterogeneous group than we had before, and some students do better in certain parts of the course. There are more students in Science 10 who do not have the math background, and generally would have (previously) opted out of the chemistry/physics area.

Colin and the teachers in his school think there is too much content in Science 10, largely because of the clientele enrolled in the course, their heterogeneity, maturity level, and background knowledge and skills (particularly in mathematics). Colin believes that students will be more successful in the sciences if there is an opportunity for repetition in different contexts—in the laboratory, on tests, worksheets, in discussions, on the computer, etc. The teachers, therefore, have met to make adjustments to the content of Science 10 and the Grade 11 science discipline courses in order to try to accommodate for these factors. Colin describes it this way:

> We've had to reduce the amount of content below what we thought we would have to...in physics we were quite concerned about the students in terms of how well they would do, in terms of math, etc., so we cut that quite a bit in terms of expectations, dealing only with one-step calculations, for example. We've moved things from Unit 3, "Matter and Energy in Chemical Change," (of Science 10) and into the beginning of Chemistry 20 (Grade 11 chemistry). We're struggling with how to reduce the content in Unit 2, "Matter and Energy in Living Systems," as we're getting some of the lowest marks in the school in

> terms of the biology content. Generally, the weather unit is breezed through, if it is even covered. It has become, in fact, kind of an option for us in order to make time for other units. People do try to work it into other work as much as possible, even into Biology 20 and 30 in some instances.

The other aspect that has implications for the teaching of Science 10 is the apparent decreasing maturity level of the students over the years. Colin says:

> I think we are seeing more junior-high behaviour in high school. ...some other variable may be changing out there through the junior high program that's bringing students into our setting who have less ability to sit down and do serious academic work.

He suggested a programming solution for this, by, for example, regrouping students who have been together in junior high school and have a pattern of disrupting classes, to separate them from one another.

Colin is using one major approach to improve student results—a focus on having students do their assigned work through continual monitoring. He believes this ties into constructivist theories: that by trying to do problems on their own, students are using their own concepts to get the answer, but when it does not work for them, they have to change to a different method. To aid in this, Colin gives students regular homework and goes over it in class, a practice which provides opportunities for students to revise their beliefs.

I asked Colin how he incorporates the STS connections into the program. He said that he and others are struggling with that aspect of the program, that they had to first find out what the content of the course was so that bringing in the STS was quite informal and done in a verbal fashion. They are trying to move to a more formal approach. He explains:

> ...if you're talking about carbon tetrachloride, you might mention that it is a toxic cleaning agent. Copper oxide can be related to the metallurgic process of breaking it down to get pure copper. We tried to put those in as little vignettes of STS. Now, I think we've done more with the first S in STS in terms of the nature of science. ...with our common lab format we have been adjusting the student activities towards reflecting a kind of Karl Popper approach. ... the overall idea of testing predictions has been a focus in the department. From a technology standpoint, I think the biology teachers have been focusing more on this than some of the rest of us, particularly since the diploma exams (for Biology 30) have emphasized technology. There's considerably more discussion of technology in the energy conservation section (of Unit 4). For the societal aspect, we start off in Science 10 by using a perspectives approach (scientific, technological, economic, ecological, and political) and try to bring in some of the STS issues if we can. We haven't really got the STS thing as much

> in Science 10 as we'd like. Some of that in terms of the STS issues is kind of working down, rather than up, because of the diploma exam.

Like many of the teachers in the province, Colin had a strong commitment to the previous structure for teaching science in Grade 10: the instruction within disciplines, that is, Biology 10, Chemistry 10, and Physics 10. I asked him if he saw any advantages to the introduction of Science 10. He replied:

> I think one of the successes of the Science 10 course is that it has given students another look at the discipline sciences in terms of making their decisions about future courses. Before, they had to look at the junior high program to assist in terms of letting them know what those disciplines were. Science 10 has also given them a little more in terms of a total background compared to the previous structure. There are more students taking physics, and I think in general, that is good. As a result, I think we have to change in the physics area....change some of our expectations and instructional approaches.

The main disadvantage he identified for Science 10 is that teachers are required to teach outside of their area of expertise, and even though he acknowledges that, for students entering high school, the most important thing they must understand is what science is and develop the attendant skills, these must always be developed in a context of a discipline science, and teachers who know that science well are the best ones to do it. Colin emphasized throughout our conversations that a curriculum change requires reflection and adjustment to continue to provide students with what they need. In his school, the science teachers met frequently to discuss problems and plan instructional approaches to meet that end, and havr been rewarded with a very high participation rate of students in each level of science courses.

Dan's Class

When I arrived for Dan's class he described what he hoped to accomplish that day then added that he would let certain topics "go wherever they led". The lesson was to develop the concepts of kinetic and potential energy based on the previous day's calorimetry experiment and the current day's experiment with a dynamics cart and ticker tape. There were approximately 20 students in the combination laboratory-classroom with lab benches the width of the room and colorful posters adorning the walls. Everything seemed to have a place, and the students were particularly well behaved and attentive. In an earlier conversation, Dan described this group as unusually quiet and hesitant to tell their own ideas, so he was having to encourage, even coax, them to speak.

Dan used an "inquiry approach", asking and challenging, more than telling, throughout the class. The students were obviously accustomed to this technique and seemed quite willing to risk providing answers and interpretations. Frequently, they referred to a concept map on energy they had in their notes to review the interconnections among various energy forms and transformations. The students were challenged to use the dynamics carts and ticker tape to collect data in order to calculate its potential and kinetic energies. The students quickly engaged in the activity with minimal guidance and were able to do the calculations required when provided with some hints regarding units.

In the second part of the lesson, Dan posed a comical dilemma for the students regarding a person swinging from a rope (Tarzan-like), analogous to a pendulum. He asked students to choose the position of maximum kinetic energy and defend their choice. Dan was careful not to let his choice be known, but asked students to think of similar everyday situations, such as swinging a golf club, to help them visualize the action.

From observing his class and from our conversation afterward, it was clear that Dan is committed to the inquiry approach and encouraging students to think problems through. Since introducing concept maps, he has found that students have clarified their thinking, so he is using them more now. He has the students keep a journal in which they reflect upon what they learned and uses the entries as a point of discussion with individual students and their parents about student progress. Dan also believes in a "hands-on" approach because students do frequent activities throughout the term. Thirty percent of the student mark for Science 10 is based on their successfully completing a project in which they work in groups to build an object that illustrates a concept such as the conservation of energy. Dan also incorporates open-ended, written response questions into his tests and feels they are important for developing student thinking.

Conversation with Dan

As Dan described his school, I realized that some very interesting and unusual approaches were being used in the teaching of Science 10, most of it emanating from the work of a group of five teachers in the school (Dan included) who were involved in an action research project. He described the project to me and acknowledged that the teachers are redefining their roles as science teachers as a consequence of their interaction in the group:

> We meet once every week to talk about where we are going and what directions we think should happen...We have an agenda of sorts that we are working towards. The action research group has been very powerful for the five of us. Mainly because it affords a chance to talk about teaching Science 10, and tricks and ideas...one person's idea will spark another idea. We have now reached a point where we have started to branch off and look at serious questions about teaching itself. What is the best way to approach science? Is it from the big picture to the small details or from the small to the big picture? Questions like that are causing us to look at what we believe to be true about teaching itself.

Dan described to me how they talk about approaches, and then one or the other will try something in the classroom and later discuss it with the group. He describes a particular discussion of the group and his summary of what it meant:

> One of the teachers said, 'I'm tired of being an expert. I feel that I have to have an answer every time a student asks a question and I do not have the time to research all this stuff.' Another teacher said, 'I just tell them to go and research it themselves.' A third teacher said, '... but the question dies because they do not pursue it.' A fourth teacher in the group said, ' Last time this happened, I asked the student to write out the question and then bring it back. What happened is that the student made a commitment to the question in writing it down and found the answer.' What this did in the group is refocused people on one of the key skill areas in the whole science program now: the idea of defining questions. Everyone realized that we had been defining the questions for the students. Maybe it's time the students defined them.

I asked Dan if the approach of the action research group to teaching Science 10 had changed over time as a result of their discussions. He replied quite affirmatively:

> I think the original situation was pretty typical. Our science teachers are much more confident in specific disciplines. The teachers in my school resisted Science 10 because of that. Prior to this action research group, the first response was to merely take what we had been doing in Biology 10, Chemistry 10, and Physics 10 and transplant it. Then, as time went on, people became more comfortable with teaching the course, and there has been a slight evolution. We agreed that energy being transformed and energy being transferred were the main themes for the course. We have members from each discipline. We believed that we can teach each other techniques and tricks that could make the whole thing better. What it did for me was really highlighted some structural things in the nature of teaching. Each of us goes to our own classroom, and does our own thing, by ourselves; and across the hall someone is doing their own thing. So, I will be making up exams for Chapter 1, and they will be making up exams for Chapter 1, but we never talk about it. I think that what is coming out of this is an awareness that teachers have been isolated. Some prefer that way, but others would like to bridge that. This group of five has come around to say, 'I have my own way of teaching, but I would sure like to learn how you do it and see if there is anything that I could use.'

I asked Dan if he hoped to share what the focus group had learned with other teachers. He explained:

> Our goal, as we learn something about the process of doing this, and maybe about our individual learnings to put it into writing and get it out to other teachers. We have a high school a short distance away, but we never talk to each other. Yet, I know people in that department are doing really neat things with Science 10.

When I asked Dan about his own approach to Science 10, he replied in a way that suggested he ascribed to helping the students construct their own meaning for the major concepts:

> I work from what the students know when they walk into the classroom. For example, if we are looking at energy in transit and transformation of energy, what I start with is a group activity where I have them draw a poster or diagram of all the connections they see. The idea being that they will unload all that they know and we discuss that. Then I work out from there to what is required for the course or to some general concept I am trying to get across. We put all the posters up and I might ask, 'What do they all have in common?' Things like the sun is a primary energy source was a common observation. They referred to it as being messy, but when we talked about it what they really meant was that it was very complex...and hard to wrap your brain around. Five major themes were brought up.. and we discussed each common theme throughout the map, the central themes for that chapter.

Dan also explained that he believes any science course must address the question of 'what is science' and so that is another starting point in Science 10:

> The group of five action researchers took our classes to a local park...we had the students make observations and then we talked about what they observed...we asked them to generate twenty-five questions that could be researched. and that fits nicely with the ideas at the start of the book—science starts with observations, seeing the world around you and then posing questions on it. From there, we worked into the ideas of Bacon and Popper. That worked nicely.

I asked Dan if the teachers in his school had considered dividing the Science 10 course to take advantage of individual teacher expertise in the disciplines. He replied that they tried this initially but met incredible resistance from the community and the students because of the discontinuity for the students of having several different teachers for Science 10, especially when they already face different teachers in each of the other courses. Dan explained his personal position on this:

> I happen to be one of the teachers who say integrate the whole thing. Do the chemistry, physics, and biology at the same time. It is very difficult to do this within the structures that are set up. In our action group, we developed two models: one having the common theme run throughout the course and have the biology, chemistry, and physics feed into it; alternatively, have the theme run throughout each of the units. They elected, this year to take it through the units, sort of as a transition. People are just getting comfortable with the idea of a theme. What we would like to do is have the theme running through a series of

> activities and feeding in information from each of the sciences...that would be our goal.

Dan mentioned that the other five science teachers in his school chose not to become part of the action research group for a variety of reasons, so we talked about why some teachers want to get more involved in the process of change, whereas others do not. He put it this way:

> I think the research group came about as a result of people having that forced change from the outside and not being content with just transplanting old ideas. It was not going right. There had to be another way—a better way. One thing we looked at initially was why people taught science. Everyone indicated it was a love of the area, the information, the knowledge, the symbols. ...the actual conducting of scientific research was not something that probably drew people to science. I suspect that most teachers have not done true science, from the point of framing a question all the way through to the answer. One of the nice things about the five people in the action group is that we all like to experiment. You have an idea, I go try it in my class and get back to you about what happened. Sometimes, these ideas grow and evolve.

Dan has some concerns about the content of Science 10, believing that it does not prepare students well for the 20 level sciences. He says:

> For example, in the biology section, everything that is done in Science 10 is repeated in greater detail in Biology 20,... and the support for Chemistry 20 is merely nomenclature and equations... and what really seems to concern the physics people that the students have a really clear idea of how to graph and to take data and convert it into a mathematical presentation. This can lead to an attitude wherein people say 'It is not really that important because we are going to do it in 20.

In Dan's school, the teachers are finding that many students are not prepared for the mathematical requirements of Science 10. He said, "One of the problems we have run into is that the junior high math (program) does not support Science 10. Students come in without any algebraic knowledge base that allows them to work with multiple variables in physics."

According to Dan, there is a reasonable articulation between junior high school science and Science 10. What frustrates him is that most students when asked 'What is science?' reply that it is 'A course that I have to take in school.' He goes on to say, "After nine years of science in school...very few will talk about it terms of a way of knowing or discovery.... It suggests to me that they are not doing a lot of inquiry prior to coming to high school."

What came through most clearly in my interview with Dan is that he believes in science as inquiry, rather than science as content, and he is much more interested in developing students' skills than in extending their knowledge base with what he referred to as the "little trivia attached to science".

I asked Dan to compare teaching Science 10 with his experiences teaching the previous discipline courses, Biology 10, Chemistry 10, and Physics 10. He was sorry to see the emphasis on diversity and on plants limited because of the need to reduce content, but he strongly supports the integrated approach to science: "I think an integrated course taught with a focus on what science is, how science is related to society, is superior to the old program."

Dan had some ideas on the direction he would like to see Science 10 take, based on his belief in the inquiry approach and his experience teaching Science 14-24. He used a 'project approach' in which the students' interests provided the focus for the class. He described it to me:

> I never used a textbook or put a note on the board...we went from project to project. I gave them a test out of the textbook and the class average was 65 percent. I think what I did was originally envisioned for Science 10...where the students are controlling and leading it off in themes that are key to their development, from their perspective.

Dan's view of the classroom learning environment coincides with the view of strong supporters of STS science education, Bybee (1994), for example. Dan prefers that students control their own learning and come to own the knowledge. In this, he supports one of the major directions taken in the new science programs. His comments and actions also suggest that he supports two other directions: inquiry-based science and integration. His view of STS seems to be that the use of everyday events as examples will make science relevant for students, while a "hands-on" activity approach will foster a better understanding of the nature of science as inquiry.

Summary of Teacher Interviews

The teachers interviewed for this study were in many ways unique in that they all had studied beyond the undergraduate degrees. Two had completed studies to the Ph.D. level, whereas the other two had completed master's degrees. In this sense, these teachers had more opportunity to reflect on the meaning of science education than do many other teachers. In addition their conversations with me forced them into more critical reflection. I feel that each of the four teachers had a personal vision of what

students need in a science education. For Ann, the inquiry method and hands-on science motivated students and provided the opportunities for learning in terms of science concepts and the nature of science as inquiry. Beth also strongly believed in a hands-on inquiry approach but was unable to use it in the situation at her school. She motivated students with relevant connections, but underlying her teaching actions was the urgency to prepare students for the next course, for which she took personal responsibility. Colin also considered preparation for the next course an important aspect of science teaching and felt successful when a large proportion of students completed science to the Grade-12 level in his school. His long-term view of scientific literacy was related to exposure to science courses. He routinely incorporated laboratory activities into his lessons and adopted a constructivist approach to teaching. Dan was also a supporter of constructivist theory, but had taken it one step further to the concept of enactivism, believing that learning was a group as well as an individual activity. For Dan, scientific literacy related strongly to an understanding of the nature of the scientific enterprise.

Each teacher was aware of the significance of their role in student learning, and I have used the following metaphors to define those roles. Colin can be described as a father figure, who took on the task of instilling in students the good work habits of doing homework regularly and preparing for examinations. Beth can be described as a mother figure, who felt compelled to do everything possible to ensure her students' success. She devoted many extra hours to preparing interesting materials and tutoring students after class. Ann and Dan can both be viewed as facilitators who provided opportunities for students to learn and placed greater responsibility on the shoulders of the students. They were less concerned with preparing students for the next course than Colin and Beth, believing that would occur through the activities they provided. Their evaluation techniques were more open-ended and less traditional than those of the others. Ann used performance-based assessment extensively and assessed students on a portfolio of their term work, whereas Dan had the students write in a journal and assigned a project with a loosely prescriptive task worth 40 percent of the students' final mark.

All four teachers interviewed believed in STS as an important component of science education. Science as inquiry was the aspect each mentioned as the most important. Dan expressed disappointment that many students reach high school with minimal understanding of what scientists actually do. Therefore, the first activity he did with his students each term involved observing natural phenomena and posing questions for

potential study. Colin, perhaps because of his extensive background of formal study in the area of STS, read more depth into the STS dimension, and approached it more cautiously than the other teachers. He expressed the opinion that a teacher must have a significant background and sound understanding of a scientific discipline before he or she can feel qualified to deliver the STS component. Beth concurred with Colin's sentiments about lack of expertise, saying that it was difficult for her to know enough connections to a topic because of her lack of background in that discipline. The importance she placed on STS as a motivation for students to study and enjoy science had her spending many extra hours in the evenings researching potential topics. The aspect of STS that Colin emphasized in the lessons I observed was the nature of science, particularly the history of scientific discoveries. Colin stated that he liked to briefly mention the uses of various chemicals as he talked about them in class, for example, that carbon tetrachloride is dry cleaning fluid, but had not yet determined how to best approach the "issues dimension". He believed that students in Grade 10 may not be sufficiently mature to go beyond identifying perspectives on an issue. The other three teachers were more likely to pull STS examples from a variety of sources and everyday experiences. The dimensions of STS that these teachers focused upon were the everyday applications of science and the environmental or medical issues that are featured in the media. Dan and Beth integrated STS into their daily lessons, as it seemed to fit. For example, when Beth taught about weather, she clipped the daily weather maps from the newspaper for the students to review and analyze, and when her students wanted to discuss how weather differed on the various planets, she let that discussion evolve in a natural way. Dan also took a natural connections approach to STS: for example, he related the swing of a pendulum to humorous scenario of a farmer swinging from a suspended rope (Tarzan-like) and a golfer swinging a golf club. Ann set aside particular times for addressing STS with students, but placed the onus on her students to find the STS connections in their readings of newspapers and media. She had the students prepare a lesson on the topic they had researched for presentation to the class. Dan placed greater responsibility for STS on the students by having them complete a major project such as designing and building a model of an energy efficient house.

These teachers all saw the value of integration of the scientific disciplines in Science 10, but also identified barriers to it. For Colin and some of his colleagues, lack of expertise in the life sciences resulted in a division of labour wherein two different teachers each instructed half of Science 10. A teacher with a background in the biological sciences

taught Units 1 and 2, and a teacher with a physical sciences background taught Units 3 and 4. This provided the student with a sound understanding of the structure and concepts of the fields of biology, physics, and chemistry and the related STS connections. Integration occurred to the extent that there were common expectations for writing laboratory reports and completing homework assignments. Colin did not equate STS science with integrated science as some proponents of STS have. When we discussed the senior-level, integrated science program, Science 30, Colin expressed the view that it might have been better designed for students who have completed in-depth studies of three or more discipline sciences, because it is only then that students would have the tools to see the connections between them. Beth cited her lack of knowledge in all three disciplines and the pressures of preparing students for the next course in the discipline sciences[7] as barriers to integration. She described the need for assistance in integrating science concepts and identified the first unit of the program of studies and the accompanying textbook chapters as very helpful in teaching science according to themes. Ann and Dan were most supportive of and successful in achieving, integration within Science 10. This success may have been related to their past experience. Ann taught junior high school science for several years prior to being assigned to a high school and, in her last school, had been implementing an experimental integrated mathematics-science program in the classroom. She could not identify any disadvantages of integration and related the need for integration to fostering scientific literacy and pedagogical theory. As she saw it, the world is integrated, and students learn best when they can connect new learning to previous learning. Dan also had experimented with integration when he taught Science 14 to nonacademic students. He was pleasantly surprised to find that when he used a project-centred, inquiry approach based on themes students achieved as well as students taught with traditional approaches. The barriers he saw to integration were the structure of the program of studies, which leaves it up to teachers to devise a method for achieving integration, and the necessity to overcome teacher comfort levels within subject areas. He and a group of teachers in his school were planning to integrate within the disciplines using themes, as a transition, he hoped, to integration between disciplines. Dan identified the theme of energy as very powerful in fostering integration of the entire course.

[7] A very small minority of students go on to take the integrated Science 20-30 program in her school (and in most schools in Alberta); most will study either Biology 20-30, Chemistry 20-30, Physics 20-30, or a combination of these.

In each school where the four teachers taught, there was a large science department with a science department head. For each teacher, the support of colleagues was important, particularly in this time of transition between old and new curricula. As teachers work with a new program in the classroom, they shape it, in consultation with colleagues, until it better fits what they perceive as the needs of their students. In Dan's school, the cooperative effort reached an amazing level with the formation of an action research group whose purpose was to find better ways of implementing the new science programs. Dan's descriptions of how they shared and learned from each other speaks volumes about the power of working together toward mutual goals. In Colin's school, the teachers met frequently to discuss better ways of delivering the new science programs and were able to make decisions about dividing up tasks and making minor adjustments to each of the courses as a need arose. For example, when they found that teachers were not able to adequately cover particular topics in Science 10, these topics would be emphasized in the appropriate 20-level course. As department head, Colin provided strong leadership and guidance to his teachers for cooperative planning and problem solving. In Ann's school, there were also frequent meetings and a sense of a common mission. The teachers encouraged each other's strengths, and particular teachers emerged as leaders in their areas of expertise: for example, Ann showed the others how to use performance-based assessment. In Beth's school, there was a friendly camaraderie between teachers, but a less formalized approach to solving implementation problems. In an ad hoc manner, teachers asked colleagues for assistance, but as Beth suggested, all teachers were very busy and it was difficult to find the time to meet for in-depth discussions.

Content versus time emerged early as an issue in the field validation of Science 10, but subsided later as teachers became more familiar with the program. Based on casual conversations I have recently had with teachers, it continues to be an issue for some teachers several years after the introduction of this program to Alberta schools. Two of the teachers I interviewed (Beth and Colin) expressed the opinion that there is too much content in Science 10. Colin relates the content issue, in part, to the characteristics of the students. He felt that the low maturity level of some of the students and their poor retention of junior high school science concepts required that teachers move slowly through the material and provide remedial help. Colin and the teachers in his school downplayed topics, such as meteorology, that do not have a direct and obvious connection to the next courses. Beth also found many of the students deficient in background knowledge and lacking a strong work ethic or serious approach to school.

Beth also provided remedial classes for students. For the other two teachers, (Ann and Dan), amount of content was not an issue. Although Ann agreed that the content load is heavy in Science 10, she suggested that integration using themes alleviated the problem. Dan's concern with content was that there may not be enough depth in Science 10 to prepare students adequately for the next course. Both Dan and Ann incorporated a high activity-based, "hands-on" style into their classrooms and saw this as facilitating the learning of concepts.

None of the teachers used the basic textbook exclusively in the classroom, supplementing it instead with handouts and exercise sheets. Colin expressed the greatest disappointment in the textbook, describing it as pedagogically unsound, because it did not provide sufficient reinforcement of concepts through practice exercises. The other teachers also found the textbook did not provide sufficient STS connections, but suggested that this was not something they had high expectations for from a basic resource.

For these teachers, Science 10 compared favourably to the previous high school entry-level science programs, Biology 10, Chemistry 10, and Physics 10. Although I sensed that each of the teachers personally enjoyed teaching the previous programs, they saw the advantages of Science 10 for students. It provided their students with an opportunity to explore each of the discipline sciences before making a choice at a stage when they are more mature. Previously, students had to choose if they wished to specialize in a particular science discipline when they were in Grade 8, a time when they were less mature and knowledgeable of the sciences. In Colin's school, the new structure resulted in more students, particularly girls, opting for Physics 20. In my position as curriculum consultant at Alberta Education I had heard of several other schools in which this was the case.

Questionnaire Analysis

In January of 1995, I sent a questionnaire (Appendix C) to the science departments of 100 schools distributed geographically throughout the province. The ideas for the questions came from the feedback and informal comments I had heard from the teachers I had contact with in my position as a curriculum consultant at Alberta Education, as well as many of the discussion points brought up by the teachers I had interviewed. Accompanying the questionnaire was a letter (Appendix C) explaining my study and a

stamped self-addressed envelope. By May, I had received 82 completed questionnaires. The following is a summary of the responses, with comments.

Personal Information

A. How many times have you taught Science 10?

1-2:	20	**7-8:**	8
3-4:	29	**9-10:**	2
5-6:	21	**11+:**	2

mean: 3-4 **median:** 3-4 **mode:** 3-4

B. What is (are) your area(s) of specialization based on your teacher training?

biology: 46	**chemistry:** 46	**physics:** 29	**science:** 21
mathematics: 10	**phys. ed. :** 5	**English:** 2	**economics:** 1
philosophy: 1	**fine arts:** 1	**counseling:** 1	

C. Prior to teaching Science 10, what subject(s) did you mostly teach?

biology: 48	**chemistry:** 42	**physics:** 32
junior high science: 28	**mathematics:** 9	**science:** 4
phys. ed.: 3	**elementary school:** 2	**health:** 1
English: 1	**special ed.:** 1	

D. How many years of teaching experience have you had?

1-2:	7	**13-15:**	10
3-5:	11	**16-20:**	12
6-8:	10	**21+:**	22
9-12:	9		

mean: 9-12 years **median:** 13-15 years **mode:** 21+ years

E. Have you had any previous experience teaching integrated science, for example junior high science or Science 10 in another province?

yes: 43
- junior high school science: 29
- science in another province: 7
- Science 14-24: 5
- science in another country: 2

no: 39

The teachers who responded to this survey are an experienced group, with an average of 9 to 12 years of teaching. One-quarter of the teachers have been teaching for over 22 years. Science 10 was implemented in 1992, so as expected, most teachers have taught it three or four times. The large majority of teachers responding have taught biology, chemistry, or physics courses and have training in these specialties. Over half the respondents previously taught a general or integrated science program, mostly at the junior high school level.

Twenty Statements about Teaching Science 10

1. The science concepts in Science 10 are appropriate for Grade 10 students.

strongly agree	1	2	3	4	5	strongly disagree
	14	30	22	12	4	

mean: 2.5 **median:** 2 **mode:** 2

2. The skills in Science 10 are appropriate for Grade 10 students.

strongly agree	1	2	3	4	5	strongly disagree
	17	35	18	11	1	

mean: 2.3 **median:** 2 **mode:** 2

3. The STS connections in Science 10 are appropriate for Grade 10 students.

strongly agree	1	2	3	4	5	strongly disagree
	12	41	16	11	2	

mean: 2.4 **median:** 2 **mode:** 2

4. Science 10 contains topics that are important for scientific literacy.

strongly agree	1	2	3	4	5	strongly disagree
	10	41	17	9	5	

mean: 2.5 **median:** 2 **mode:** 2

These data suggest that most teachers agree that the learner expectations in the Science 10 course of studies are appropriate for Grade 10 students and that Science 10 contains topics important for scientific literacy. In their written comments, several teachers expressed concern that the mathematics requirement in Science 10 is too difficult for many of the students enrolled. Before the introduction of Science 10, students with lower achievement in mathematics were streamed into Biology 10 and were able to avoid any physical science component in their high school years. To circumvent this problem, some schools are now offering Science 10 at two levels[8]. The lower level de-emphasizes a quantitative approach, a move which, in essence, reduces the rigour of the physical sciences portion of the course. These students are then streamed into biological sciences, which are seen as requiring a lower level of mathematics. Alberta Education consultants had recommended to teachers and administrators at information sessions that it would be preferable to enroll students prior to or concurrently with Science 10. One teacher respondent described another creative solution for this problem: "I am currently teaching a combined program of Math 10/Science 10. This has been of enormous benefit."

Some of the comments addressed to Statement 1 indicate concern about the standard for the course. A few teachers suggested that the Science 10 course does not meet the standards for an academic high school program. For example, they said the following:

"Not enough academic content—too superficial."

[8] Based on conversations with teachers.

"The material is rather simple for the most part."

"Science 10 is too watered down."

These comments may result from comparing Science 10 to the previous science program offered at the Grade-10 level. For example, a teacher of physics may be looking for the same number of physics concepts in Science 10 as there were in the previous Physics 10 (Also refer to Statement 16 for more on this topic).

5. I am able to teach Science 10 as an integrated science program rather than as a series of mini science discipline courses.

strongly agree	**1**	**2**	**3**	**4**	**5**	**strongly disagree**
	4	10	30	24	14	

mean: 3.4 **median:** 3 **mode:** 3

Most teachers are satisfied with their abilities to successfully implement Science 10 (see response to Question 8), except when it comes to teaching it as an integrated science. Some sample comments were as follows:

"I still tend to teach it as four separate disciplines."

"It's very difficult to break the habit of viewing it that way, as 3 or 4 separate knowledge areas."

"I feel that in order to teach this course effectively the teacher must have a solid high school level in all three disciplines."

As mentioned previously, neither the course of studies nor the basic resource for Science 10 provide exemplary direction on integration. As well, teachers usually specialize in a particular scientific discipline at university. Therefore, it is not surprising that teachers are struggling with this, particularly if their training is in a single discipline. Showing teachers how to do this can make a difference. Two teachers who took part in the field validation, and who were recipients of an intensive workshop on integration, were able to successfully integrate interdisciplinary concepts using large themes such as "solar energy".[9]

[9] According to a presentation these teachers gave at ATA Science Council.

6. It is easy to integrate the STS connections into the science concepts in Science 10.

strongly agree	1	2	3	4	5	strongly disagree
	8	23	30	14	7	

mean: 2.9 **median:** 3 **mode:** 3

Integrating the STS connections is challenging for teachers. Very few comments were added to this question, so it is difficult to determine how these teachers are feeling about this aspect of Science 10. My conversations with teachers indicate that they are also struggling with the integration of STS, even though they consider it an essential aspect of science education (see also, responses to Statement 18). The amount of content[10] that must be covered, their lack of this kind of knowledge in disciplines outside their specialty, little emphasis of STS on standardized assessment instruments, and the difficulty in finding appropriate resources are the main reasons teachers for their not placing more emphasis on this dimension.

7. There is enough time to teach all of the concepts in Science 10.

strongly agree	1	2	3	4	5	strongly disagree
	3	11	5	15	48	

mean: 4.1 **median:** 5 **mode:** 5

There is a concern regarding the amount of material in Science 10, with about two-thirds of the respondents replying that there is inadequate time to address all of the concepts. Some representative comments were as follows:

> " In general the curriculum ...is overloaded with content. Students never really get a chance to practise and solidify a concept before moving on to the next."
>
> "The program tries to teach too many concepts rather than...a few concepts in an excellent way."
>
> " Teaching Science 10 is like skipping a flat stone on the top of water–you just touch the surface for a brief time."

[10] It is my experience that when teachers speak of content they are usually referring to the science concepts that must be addressed

These responses corroborate the comments made by teachers interviewed for this study and the majority of teachers and students who took part in the field validation of Science 10 (Refer to student responses in the next section).

One teacher elaborated on a solution used to assist with this problem:

> ...a group of teachers...have formed committees to decide how to remove some of the content so that students and teachers can have more time to address STS connections, process skills...students at this level need to spend time developing and testing questions and interpreting results. This is science.

All of the teachers interviewed described group collaboration efforts as helping them to make decisions about content.

8. I feel adequately prepared as a teacher to teach Science 10.

strongly agree	**1**	**2**	**3**	**4**	**5**	**strongly disagree**
	31	31	10	6	4	

mean: 2 **median:** 2 **mode:** 1 and 2

9. I often seek assistance from colleagues when I encounter difficulty with unfamiliar topics in Science 10.

strongly agree	**1**	**2**	**3**	**4**	**5**	**strongly disagree**
	25	26	11	7	13	

mean: 2.5 **median:** 2 **mode:** 2

Although teachers are confident in their preparation to teach Science 10, when they do need help, they are most likely to turn to their colleagues for assistance in implementing this new course. In small rural schools, teachers must cope on their own. Two teachers made these comments in reference to this statement: "I am the only science teacher in the school;" and "No one is available." Another commentor described the advantage of being a generalist: "Others seek assistance from me as I am a general science type." All of the teachers I interviewed said that they needed help to teach Science 10 and turned to colleagues most frequently, but also to resources, friends, and relatives for assistance.

10. I enjoy teaching Science 10.

strongly agree	1	2	3	4	5	strongly disagree
	14	35	18	10	8	

mean: 2.7 **median:** 2 **mode:** 2

This response is puzzling, given the negative comments to Statements 7 and 12. Even though the majority of teachers believe Science 10 is overloaded with content and would like to change it, they enjoy teaching it. This could be related to the fact that students enjoy being in Science 10, as reported in Statement 19.

11. Science 10 is best taught by two or more specialist teachers in a team teaching mode.

strongly agree	1	2	3	4	5	strongly disagree
	12	11	33	12	14	

mean: 3.1 **median:** 3 **mode:** 3

About a quarter of the respondents believe that Science 10 should be taught in a team teaching mode by specialist teachers. This does not bode well for the future of Science 10 as an integrated program. Of the teachers I interviewed, Colin had chosen to share the teaching because of the desire to provide students (and the demanding community) with an expert in each science. He then felt more confident in his ability to discuss appropriate STS connections and to prepare students well for the next discipline course. Others dismissed this option because of the logistics of arranging it and because they felt confident in their ability to learn what was needed to instruct in a science discipline that was not their specialty.

12. There is not much I would change about Science 10.

strongly agree	1	2	3	4	5	strongly disagree
	2	7	13	27	33	

mean: 4.0 **median:** 4 **mode:** 5

The majority of teachers believe that Science 10 could be improved. Based on the comments, the major concern is the number of topics . Many teachers provided suggestions for improving Science 10:

> "It needs to be changed from the theoretical structure... to applied science."
> "I would probably drop the weather chapter."
>
> "Reduce volume by determining what skills and knowledge are crucial to the 20-level courses and teach them well."
>
> "It would be nice to have the option of covering some topics in depth, with some rigor."

Another respondent gave an opinion as to why Science 10 was flawed: "University experts had far too much influence in designing Science 10, 20, 30."

13. The resources, including the textbook, to support the teaching of Science 10 are adequate.

strongly agree	**1**	**2**	**3**	**4**	**5**	**strongly disagree**
	4	16	21	13	28	

mean: 3.5 **median:** 3 **mode:** 5

Many teachers are dissatisfied with the Science 10 resource, *Visions 1*, but not quite as many as are dissatisfied with the course of studies, as noted in Statement 12. The dissatisfied group provided the bulk of the written comments, some quite pointed. Some of the example comments were as follows:

> "Textbook is very poor!"
>
> "Textbook is inconsistent—sometimes excellent—other times pathetic"
>
> "The textbook deals with the course as separate disciplines."

Teachers expected more support from the basic textbook. Teachers whom I had interviewed found that they had to supplement with alternative resources, a sentiment that is echoed in this response to the questionnaire: "The resources we have put together in our school are excellent. The *Visions* textbook is limited."

14. Science 10 prepares students well for 20 level science courses.

strongly agree	1	2	3	4	5	strongly disagree
	2	10	29	17	24	

mean: 3.5 **median:** 3 **mode:** 3

Many teachers expressed concern about the adequacy of Science 10 to prepare students for the 20-level courses. Sample comments were as follows:

> " More concepts in chemistry and physics should be added to the course so students are better prepared for the next level of courses in these subjects."
>
> "Science 10 does not provide much background knowledge for Chem 20 or Physics 20."
>
> "Biology 20 course has little to do with Science 10"

Preparation for the next course was also a concern for the teachers I interviewed. There was a strong sense of responsibility for the future of students.

15. Students are doing reasonably well in Science 10.

strongly agree	1	2	3	4	5	strongly disagree
	6	36	22	14	4	

mean: 2.7 **median:** 2 **mode:** 2

16. Science 10 is too difficult for the students enrolled.

strongly agree	1	2	3	4	5	strongly disagree
	5	24	20	21	12	

mean: 3.1 **median:** 3 **mode:** 2

Teachers were divided on the difficulty of Science 10 for students, and how well students were performing. Many teachers identified factors outside the program, such as student preparation in junior high school and student work habits, as the cause of poor performance in Science 10. Here are some sample comments:

> "Science 10 seems well suited for academic students. Some of the weaker ones have difficulty with concepts in the physics and chemistry area (because of the math), although I believe that anyone with good work habits can master it."

"Science 10 is a good course for the top 20% of students. However, the 60% of the students in the middle...have a great deal of difficulty."

"The only difficulty we have in our school is with students who enter Science 10 with a weak background in Junior High Science."

"Not too difficult, just too much."

"There is a quantum leap from Science 9 to Science 10:
qualitative ----> quantitative."

" Students need to work harder."

The concern about the adequacy of student background was also expressed by the teachers I interviewed. They reported that students in their first year of senior high school needed a great deal of coaching, and coaxing, to do their homework and prepare for examinations. Some were lacking the prerequisite skills, particularly in mathematics, and the knowledge for a rigorous course such as Science 10.

17. An integrated program like Science 10 is better for students than a single discipline program (Biology 10, Chemistry 10 or Physics 10).

strongly agree	**1**	**2**	**3**	**4**	**5**	**strongly disagree**
	15	13	15	14	25	

mean: 3.3 **median:** 3 **mode:** 5

About half the respondents believe that the previous single discipline courses of Biology 10, Chemistry 10, and Physics 10 are better for students. A majority of the respondents could not see any advantages to integration. Some of the comments regarding Question 17 were the following:

"Some students cannot achieve the level of success in Science 10 that they might in the 'old' programs because they excel in one discipline."

" It allows students to determine which areas they are good in."

"I thought it was useful in making wise course choices in Grade 11 and 12."

Some teachers interpreted this question in terms of what they would prefer, judging by the following comments:

"I liked the way it was before."

" Most (teachers I know) still would rather have the Biology 10, Chemistry 10 and Physics 10."

The responses suggest that many teachers are not convinced of the need to have changed the structure of the senior high science programs. In their view the old structure was working fine. The teachers I interviewed were more positive about the changes.

18. The STS emphasis in Science 10 improves students' decision-making abilities on issues related to science.

strongly agree	**1**	**2**	**3**	**4**	**5**	**strongly disagree**
	7	23	28	18	6	

mean: 2.9 **median:** 3 **mode:** 3

Based on the responses to Statements 3 and 4, teachers are in favour of including STS connections in the curriculum, but are less certain about the effectiveness of these topics in preparing students for decision-making. This may relate to how teachers interpret STS, as applications of science or more broadly as implications of science; or it could be related to their view of the maturity levels of students and their abilities to understand difficult issues. None of the teachers provided additional comments for this statement, however, some of the teachers I interviewed were of the opinion that 14–year–old students may not be able to comprehend issues beyond a superficial level.

19. Students generally like Science 10.

strongly agree	**1**	**2**	**3**	**4**	**5**	**strongly disagree**
	3	30	25	17	7	

mean: 2.9 **median:** 3 **mode:** 2

Despite the generally negative feelings teachers have toward the Science 10 program, based on responses to Statements 7 and 12, they are more likely to think that students like the program than not. Their opinions are corroborated by the responses of students summarized in the next section.

20. Parents and the community have reacted positively to Science 10.

strongly agree	1	2	3	4	5	strongly disagree
	1	12	48	14	7	

mean: 3.2 **median:** 3 **mode:** 3

From their responses and comments, teachers were not sure in their response to this Statement. In this sense it may not have been a fair question to ask teachers, since it would not be clear as to how aware the community would be about the changes to the program.

Summary of Teacher Responses to Questionnaire

The teacher responses to the twenty statements about Science 10 suggest the following areas of satisfaction regarding the implementation of Science 10:

- the topics, skills, and STS connections chosen are generally appropriate for students (responses to Statements 1, 2, 3, and 4)
- teachers generally feel confident in their ability to teach Science 10 (responses to Statements 6, 8, and 9)

Teacher responses suggest the following areas of dissatisfaction regarding the implementation of Science 10:

- there is too much content in Science 10 (response to Statements 7 and 12)
- the basic resource for Science 10 is less than adequate (response to Statement 13)
- Science 10 does not work well as an integrated program (responses to Statements 11 and 17)

This group of teachers was divided on the following issues related to the implementation of Science 10:

- does Science 10 prepare students adequately for the next sequential courses? (response to Statement 14)
- is Science 10 too difficult for the students enrolled? (responses to Statements 15, 16)

One question that arises in analyzing the teacher questionnaires is "Does teacher background have any relationship to the type of response given to the particular questions in the questionnaire?" For example, are teachers who have experienced

teaching junior high school science more supportive of the direction of the Science 10 program than those who have taught only disciplinary science in high school? Is there any difference in teachers' replies if they have experienced a variety of discipline programs compared to the teachers who have experienced only one discipline? Do years of teaching experience have any relationship to the teachers' replies? Various analyses of the questionnaire responses to determine this were unsuccessful in demonstrating a cleat cut answer to this question because several of the statements related to attitude toward Science 10, for example statements. For most of these statements there were small groups of respondents with both multidisciplinary experience and more singular experiences with teaching science at either ends of the scale. The largest group of respondents chose the middle ground neither expressing great favour or disfavour for Science 10, again regardless of their background.

In the more qualitative part of this study that relied on interviews and class visitations I found that all of these teachers were generally more positive toward Science 10 compared to the quesionnaire respondents, and the two teachers I interviewed who had a background teaching integrated science were the most positive.

Student Responses to Science 10

If educators wish to promote science literacy and generate greater interest in science-related careers, they would be advised to take careful note of student perceptions. Wanting to hear the voices of the Science 10 students, yet realizing the limitations of this study, I decided to review the questionnaires that students had completed during the field validation of Science 10 during the 1991-92 school term. Although their experience of Science 10 may be coloured by the fact that it was the first time their teachers were teaching the course, I still believe there is something to be learned by discussing their responses to the major shifts in emphasis in Science 10 and then comparing them to those of the teachers in this study. Particularly, this analysis will increase the validity of the results, by providing another source of information. The questionnaires I analyzed (Appendix D) had been sent to field test schools with the instruction to the teachers that they were to be administered at the end of each unit of study. This was a voluntary activity and the number of responses received at Alberta Education from the approximately 4000 students in the field test was about 600.

The closest Alberta Education came to asking students for their opinions was in the form of the questionnaire administered by teachers during the field validation. Do students wish to be heard? These comments would indicate yes, but also voice a sense of powerlessness:

> "This Science 10 course should have been discussed with more students and should have been an option before it was so cruelly forced upon us."
>
> "I don't know what changes I would like to see because no matter how much I don't like something, we'll do it somehow."
>
> "I didn't dislike it but I didn't like it. It was something that I had to do and I did it."

Too often we may assume that students are not thoughtful enough on the subject of schooling to provide insightful comments. One of the most interesting comments made by a student suggested that the whole school system needs revamping: "Changes to the school system! 3-4 years basic school start at around 10 years. Choose career and spend rest of school time on it."

The student responses were gathered on a voluntary basis; however, when a teacher asks students to complete a questionnaire that is described as coming from government officials, one must assume that the student does not consider this an optional undertaking. No formal analysis was ever completed on the student replies, an omission which also speaks loudly of the significance placed on their viewpoint. I hope this analysis of student questionnaires can serve as a reference source for future curriculum developers.

Through this analysis, I hope to uncover themes emerging from the students written comments as they speak to curriculum developers through the semistructured response forms. What did students like about the new program? What did they dislike? What would they change? These were the three questions asked of the students. What do their answers tell us about the perspective of the students toward this curriculum and what do their comments tell us about the values and point of view of the curriculum and textbook developers? Is there any indication of the students' views of science education, and of science, in their comments?.

Curriculum change in North America tends to be dominated by the technical approaches to scientific management popularized in 1949 by Ralph Tyler's *Basic Principles of Curriculum Instruction* (Aoki, 1985, as cited in Blades, 1991). The major players are

those who belong to the established set of individuals and organizations who have traditionally been appointed to curriculum committees: government curriculum advisors, teachers, administrators, postsecondary educators in science, and selected members of the community. The largest group most conspicuously marginal to the curriculum design process in most jurisdictions are those most affected by it—the students. During their twelve years of education, students gather many opinions and ideas about education (Blades, 1991). Student opinions are not often sought in a curriculum revision, yet students are as directly affected by the changes as their teachers. The validation of curriculum by students is often an overlooked step in the process of field testing. We hardly know anything about what students think about educational changes, because no one ever asks them (Fullan, 1982, as cited in Blades, 1991). In the hierarchical structure of curriculum reform, students do not have a powerful position.

In the recent reform of senior high school science programs in Alberta, it was difficult to obtain a seat at the discussion table because of the keen interest by a broad spectrum of members in the community. Those partaking in the discussions included business people and professional scientists as well as educators. This round of curriculum reform provided the greatest opportunity to the greatest number of interest groups of any revision process ever attempted in the past. Nevertheless, there never was any direct representation by students. This is an omission criticized by David Blades in his doctoral dissertation (1994). The group that would be expected to voice the students' concerns most strongly might be the parent representatives of the Home and School Association, who were also present at the discussion table. In my observations of their involvement, I would conclude that these parents most strongly represented an elite group of students, those likely to go on to postsecondary study at university.

Student Comments on STS

Science education has traditionally been dominated by, and continues to reflect, rational empiricism (Jacknicke & Rowell, 1987). In this view, knowledge is separated from the knower and science is described as objective and unbiased. This perspective has resulted in a technical approach to curriculum development, implementation, and evaluation. In high school science curriculum reform, the structure of the discipline as described by Schwab (1961) and the hegemony of the academic world have combined to produce academically rigorous curricula with the major goals of imparting knowledge and enculturating students into the world of the scientist—supposedly to

ensure that important scientific knowledge is preserved and that there is a sufficient pool of young scientists to carry on the tradition. The social interactions that relate to developments in science and the impacts of those developments on society and the environment have largely been ignored in the curriculum. The recent revisions to the senior high school science programs in Alberta have tried to broaden this interpretation of science to include other orientations through science, technology, and society (STS) connections. This has largely met with antagonism from the academic scientific community, its severest critics describing STS as less than valid science, concerned with opinions and emotions, and a corruption of the 'pure' science that has been passed down to us by the great scientists of the past. The rationale for STS resides in the wider world that lies outside of the scientific laboratory, and, being more concerned with the issues and problems that face 'lay people,' STS is of greater interest to most students than truths about nature, mathematical interpretation of scientific concepts, and scientific methods. According to the responses to the questionnaire, students seemed to enjoy any connections that were made from science concepts to their everyday life, and when asked for ways to improve Science 10, they suggested more STS connections, particularly as they relate to environmental issues. For example, students said:

> "More awareness environmentally if we start earlier learning about our world and problems e.g., greenhouse affect, acid rain, etc. Learn what they are, what they do, how to help get rid of the problem and keep it away."
>
> "I experience weather every day of life and always will. Meteorology is practical. I don't really ever believe I'm going to need to know how to do formulas in the real world. Formulas and significant digits are not a part of everyday life."
>
> "Make sure to connect everything learned to our everyday lives and show the practicality in learning the information."
>
> "Topics that have more that we can identify with and that may capture out interests and attention. Like things that we deal with daily and how we are affected by these science topics."
>
> "I also enjoyed everything that related to everyday life. Things that solve those little mysteries of life."
>
> "When you relate the topics to the environment and our own household this unit doesn't seem so foreign."
>
> "Maybe more information could be given about the different impacts of hydro-electric and coal burning energy supplies on industry and the environment. I think information like this would be valuable to students living in these times. More information on environmental issues in general would be both interesting and useful."

Teachers who defend traditional science instruction warn that time spent on STS content diminishes preparation for the next science course. Fewer science concepts will be learned and general achievement will suffer. Is there any validity to these claims? The answer is probably not. The traditional high school science courses in North America do not stand up to scrutiny as well as one might expect. The fear that increased STS content will significantly diminish the amount of science content acquired by students and thus compromise their achievement at university, seems to be unwarranted (Keeves, 1990, as cited in Aikenhead, 1994). Students in STS classes can make gains in thinking skills, such as applying scientific content to everyday situations, critical and creative thinking, decision making, and improve their attitudes toward self-reliance, civic responsibility, science, science classes, and learning science as a result of STS content and STS teaching methods that involve students interactively (Aikenhead, 1994, Yager, 1989, 1992)).

"Hands-on" Science

Most science curricula of the past 40 years have emphasized an activity-based experimental approach, based on the premise that practical work will lead to concept formation in students and an implicit understanding of what it means to do scientific investigation. The revisions to the senior high school have a strong focus on scientific inquiry, but with the additional goal of fostering enthusiasm for science. It is suggested that for greatest effectiveness, students do more than carry out experiments, but also design and evaluate them. Pickering (1987, in Gabel, editor, 1994) states that learning and enthusiasm can be fostered by laboratory activities that are geared towards student needs and that show students they can overcome challenges.

When students were asked in the questionnaire "what did you like most about this course?", overwhelmingly students (over 90 percent of respondents) referred to the laboratory work, the experiments, or the "hands-on" activities. These are some of their comments and insights:

> "I liked all the experiments we did. It was a very active unit. It let us use our own minds a bit."
>
> "I would like to see more hands on activities with in all the units for I feel that it is easier to learn by doing it than just by reading it."
>
> "I enjoyed doing labs and experiments and also discussions. I think we should do more discussions, experiments and labs. Maybe even field trips. I think we do too many notes and write a lot."

"You did more stuff "hands on" than sitting around taking notes that you never ever learn from."

"More labs to be done. More experiments so we aren't always sitting, we would actually be up doing. The more you do the more you learn, kind of like life and the less you sit, the more you learn."

"We should see more experiments, they show you what you're learning, it makes you understand a lot more."

"You don't learn as much from reading your text as you do when you are doing experiments."

Lavorowitz and Tamir (in Gabel [Ed.], 1994) report that rationalizations for practical laboratory work include, but do not always attain the following:

- the offer of opportunities to identify student misconceptions
- the development of cognitive skills related to problem solving, analysis, and decision making
- the promotion of an understanding of the scientific enterprise
- the development of various manipulative, organizational, and group work skills
- the development of scientific attitudes and positive attitudes to science

The laboratory is considered an important place of learning in the science curriculum, a place where students can interact with their existing conceptions as well as develop new ideas.

Teaching Approaches

The STS classroom is described as a dynamic place in which learning is negotiated between teacher and student. The teacher is viewed as the facilitator of the student learning, and much of the classroom activity is directed by student interest and important issues of the day that relate to the science concepts outlined in the program of studies. According to constructivist and STS approaches to science teaching, teachers are expected to change their traditional role from that of provider of knowledge to that of fellow-learner, reciprocator, and negotiator (Ebenezer & Zoller, 1993). What students had to say about the teaching approaches used tells us how they have interacted with this approach, some of what they enjoyed, and what they would like to see emphasized:

"The theory of having more thinking involved is good but it starts off too hard. I know myself that it was hard after 9 years of memorizing facts to all of a sudden thinking hard about what I am doing. In a nutshell this course should ease students into the course."

"The unit consists of many problems, that made me think."

"Take it slower, cut out some of the questions and have more class discussions."

"Have lots of group projects where students design it themselves."

"Try to make it more fun."

"I didn't like all the memorizing."

"Use plain English instead of all the complicated science terms."

"Public hearings were the thing I enjoyed most about Science 10 so far."

"More homework which is hands-on at home."

"More open discussions. Less of the teacher talking."

Within any population of teachers there will be three groups: those who are opposed to an STS approach, those whose philosophy of science education is more or less consistent with an STS approach, and those in the middle who can move in either direction. The third group may embrace STS instruction after they go through the process of teaching an STS course and there is the availability of instructional materials (Aikenhead, 1994). Welch (1969 as cited in Aikenhead, 1994) reported that student outcomes are far more influenced by the teacher than by a particular syllabus. This is reinforced by the student comments:

"When you have a good teacher the course works good."

"Mr. M. made it fun and interesting."

If classrooms are to be made stimulating, supportive environments where students may question and develop their interests in science, an important educational goal will have been achieved. Science-friendly attitudes may be encouraged at the secondary level by ensuring that enthusiastic, knowledgeable, and inspirational teachers offer courses that regularly employ dynamic and relevant instructional methods (Ebenezer & Zoller, 1993).

Mathematics in Science

The introduction of mathematics into science was the first such experience for most students. What did they think about this? It has been concluded that many students drop out or avoid science due to the mathematical requirement. The largest enrollments in senior high sciences have traditionally been in biology, the common belief being that

biology requires the least amount of mathematics, and is therefore the easiest. However, advancements in the field are rapidly changing biology into the most rigorous science, according to some educators.

Teachers identified a poor background in mathematics as an impediment to the successful implementation of Science 10. It is obvious from their comments that some students did not enjoy the mathematical component of Science 10, but some found it a stimulating addition:

> "I didn't enjoy calculating heat capacity (and other things)."
>
> "Myself and probably an abundance of the class did not enjoy the mathematical problems, but I do realize they must be done."
>
> "I really enjoyed the section in which we did a math style unit ($\Delta H(fus)$, $Q = Mc\Delta T$, etc.) I liked how we see the data, plug it in and get a number that actually means something."
>
> "Sometimes I think they should make a science-math course with all of the formulas."
>
> "The computations ($\Delta H(fus)$ were interesting and I find that math is finally showing a use in my future."

Most treatises on scientific literacy make some reference to the role of mathematics in science. In the AAAS Benchmarks for Scientific Literacy (1993), expectations about the nature of mathematics are given a chapter of their own. In the introduction to this section, the following statement is made:

> Because mathematics plays such a central role in modern culture, some basic understanding of the nature of mathematics is requisite for scientific literacy. To achieve this, students need to perceive mathematics as part of the scientific endeavour, comprehend the nature of mathematical thinking, and become familiar with key mathematical ideas and skills.
>
> (AAAS, 1993, p. 23)

The Alberta Science 10 program of studies refers to an ability on the part of the student to "use mathematical and statistical calculations" when operationalizing communication and organizational skills (Alberta Education, *Science 10,* 1995, p. 4).

Time Issues

The amount of material in this course emerged as an issue during the field validation and during the implementation stage, with some subsequent changes being made to the program of studies and textbook. It has become less of an issue after implementation as

teachers became more familiar with the course. The amount of time allowed for courses with credit allocations linked to time (Carnegie unit) has been hotly debated for many years now. The current structure within schools appears to preclude allowing those students who require more time for learning to proceed at a slower pace. The debate of depth versus breadth in the science curriculum has recently been revived by the American Association for the Advancement of Science (AAAS) in their publications *Science for all Americans: Project 2061* and *Benchmarks for Scientific Literacy*. In a discussion of scientific literacy, the authors describe the present curricula as "overstuffed and undernourished" and recommend that schools should not be asked to teach more content, but rather to focus on "what is essential for scientific literacy." These sentiments were strongly endorsed in the comments made by the Science 10 students:

> "Less material because there is too much to cover in too little time."
>
> "Have more time to learn and understand it all."
>
> "The most obvious and desperate fault in Science 10 is the rate in which we cover things. We get a period or two to absorb certain topics. (A period or two can be less than a day.) This is ridiculous."
>
> "I think that the amount of information on each topic should be increased drastically, especially in the weather unit. It was like a slave-driving prison camp."
>
> "Have it as a full year coarse(sic)because it goes a bit to fast."
>
> "We should be given more time to complete this unit. I think we were forced to cover the materials too fast."
>
> "It shouldn't be such a broad variety, we should study a few things more in-depth.. We need to take the subject a bit more deeply. All we basically did was skim the top."
>
> "I think this course should be a 10 credit course. Instead of taking up 2 blocks let it take up 4. More time to do more stuff."

Course Structure and Integrated Science

Leaders in the STS movement see a strong link between STS programs and interdisciplinary, or integrated, science. For example, Yager, in *New Trends in Integrated Science Teaching Volume VI* states that "STS is one reform effort which transcends a single discipline. STS is a major force in bringing traditional disciplines together" (as cited in Unesco, 1990, p. 44). Holman, in this same report, states that "STS is concerned with the application and issues of science in society. Taking such applications and issues as starting points is an effective way to integrate a science

course. Such issues are by their nature interdisciplinary" (as cited in Unesco, 1990, p. 49). Some comments made by students about the integrated aspect of the course were as follows:

> "I like the idea of combining three things together. This is good. Don't change that."
>
> "I do not enjoy the fact that I have to take biology, chemistry and physics if I only want to take chemistry and biology. The physics part of the unit screwed up my whole year and may cause me to lose my credits."
>
> "Overall though I think that it is an excellent idea to have science as one subject, for it allows us to study it as a whole, rather than in three parts, which has traditionally been the format used in the past."
>
> "Overall I'm pleased that I don't have to take three separate subjects and on the whole, you've done a good job of combining them."
>
> "I am very pleased of being able to take all three sciences together and I hope I might experience the same course in grade 11 .I'd like to see everything specified more so we know what's biology, chemistry or physics because I get mixed up."
>
> "I would like to see more of physics, chemistry and biology. I think it was a mistake to bring in a new Grade 10 science."

Again and again, the trials of integrated courses in various parts of the world have confirmed teachers' lack of enthusiasm when teaching outside their usual scientific discipline (Hahmed as cited in Unesco, 1990, p. 97). Some of the negative response to integrated science in Science 10 may be a reflection of the teachers' lack of support for it, something I have discussed in other sections of this thesis. It is interesting to note that the student comments in favour of integrated science outnumbered the negative by far.

Textbook and Curriculum

The basic textbook has a strong influence on the curriculum in the science classroom. The students in the field test had to work with a draft textbook on photocopied pages and had many suggestions for improvement, because I believe they felt that their comments would be considered and used in revisions to the book:

> "Not so many checkpoint and chapter questions, and not so many notes."
>
> "Too much reading.'
>
> 'I think it could have been more in-depth. That probably would have made it more interesting."
>
> "More comprehensive explanations of some of the topics would be helpful."

"Have the textbook more organized so it will be easier to read and get information from."

"I would suggest to have more details on each of the topic."

"Leaving things out that would usually be in LA Example: writing a report, brainstorming, flow charts."

"Maybe some small "Fun With Science" projects or experiments to try at home."

"I didn't like the fact that I had to go to other sources to get the full picture of what I was learning about."

"The biographies and career sections are a waste of paper. Not having so many of them would be better."

"The book seems to talk down to me the language used reminded me of my text book in grade 6."

"Should have more pictures to help people visualize concepts."

Dislike for the textbook was one of the stronger messages given by teachers in the questionnaire responses, in the interviews, and in general conversations. Teachers rely on the basic resource to provide the direction and that they feel may be lacking in the course of studies. They hope that students can use it independently to learn from and for reinforcement of their instruction.

Neither of these aspects was strong in the *Visions 1* resource. The developers viewed the resource as a repository of information surrounded by connections and discussion about the topics, not as a workbook for independent study. These differing views of a resource led to disappointment and dislike. Teachers were looking for a self-contained course with many reinforcing assignments, whereas the textbook developers saw the textbook as a source of information with connections that provided motivation and interest, along with some thought-provoking questions. Unfortunately the style of the book, with dense text and too many examples of verbose discussions and explanations could not sustain the attention of students, raised on the "quick bites" of contemporary media, long enough to provoke much thought and interest. Teachers turned to worksheets for reinforcing concepts[11]. Another problem that arises in writing a textbook for an STS program is the need to remain contemporary and in tune with the

changing interests of students. It may be that resources for STS programs cannot rely on traditional textbooks, particularly if instruction is to become more student directed.

Summary of Student Responses

To summarize the viewpoints of the students as expressed through their responses to the questionnaire distributed to field test sites during the validation of Science 10, and drawing also on my son, Steve's, experiences in Science 10, I have written this story entitled, *A Semester in the Life of A Science 10 Pilot Student.*

> Imagine yourself a student on the first day of the field test of Science 10. You are new to this school and have just left the security of your junior high school and have congratulated yourself on having made it safely to the right classroom, without being pushed around or harassed by one of the senior students. You are taking Science 10 because you were told that you are a reasonably good student and everybody has to study science in Grade 10. The name is somewhat comforting to you because you have taken Science 7, Science 8, and Science 9. As you enter the room, you notice that there are many students crowded into a "lab classroom," and you will have to sit on a tall, hard stool and peer around a chrome-plated, inverted J-shaped water tap. You look for a familiar face and are shocked to see only one—that of a student you never associated with in junior high school, because he was not "cool".
>
> Your teacher looks friendly, but slightly overwhelmed by the large number of students in the room. Stacked in front of her are many piles of photocopied sheets, shrink wrapped in plastic. She hands you one of these 'textbooks' and another single sheet titled 'course outline'. After she has the attention of the class she explains that the school is "piloting" Science 10, which means it is a brand new course that is being tried out by some students in the province. You're not too sure you're happy about being a 'guinea pig' for this experiment. The teacher goes on to explain that this means that there won't be a real textbook but instead this stack of photocopied sheets about which you will be asked to give comments as it is the pilot text. This doesn't bother you too much because in junior high school science you didn't have a textbook to take home either, just one to use in class. Your teacher tells you that at intervals during the semester you will be asked to fill in a questionnaire about the course that will be sent to Alberta Education (the government) who, your teacher says "has decided that the senior high school science program needed changing". She explains that previously students could take 'discipline science courses' called Biology 10, Chemistry 10 or Physics 10. She tells you she taught Chemistry 10 last year. In Science 10, you will learn something about each of these disciplines as well as some meteorology. You worry this must be something very difficult and strange until you overhear a student nearby say that this is about the weather. The weather—in Grade 10? You're a little worried about getting the good marks your parents expect but decide that this course will probably be okay since your teacher seems to know what she's doing, even though she does not seem overly enthusiastic about being asked to teach this new course.
>
> You've survived two months of high school and you're feeling quite smug. You've made new friends and your marks are okay. Today in Science 10 the teacher handed you a questionnaire that asks you three questions about the

course: What do you like about the course? What do you dislike about the course? and What would you change about the course? This is a strange experience as you've never been asked to evaluate a course before. You're quite pleased to be asked your opinion, but the teacher has only allowed the last few minutes of the class time to complete it so you'll have to think quickly as you have to rush to get to your next class in time. What do you like?—that's easy—all the experiments. You hadn't been allowed to mess this much with equipment and materials in junior high science, and never in elementary school. There were a lot of rules about working in the lab; your teacher says because of the large class size, but still it was fun. And the amazing thing is that you are learning from it. The hands-on activity keep your mind from wandering—unlike the lectures, the reading, the notes and questions from the book which you list under the things you don't like. You also enjoyed the group work, class discussions, and learning about how science applies to everyday things, including (a little surprisingly) the weather. Under things you would improve, you write that you would prefer a real textbook with nice colourful pictures instead of this set of photocopied sheets in which your teacher keeps pointing out errors. You would also like to learn more about the environment and how people could improve it. All in all you are enjoying Science 10, even though your marks are not that high because there seems to be so much to learn in so little time.

Wow—the end of the semester and soon you'll be writing an exam worth 30 percent of your final mark. That's a lot of pressure, but you're getting used to it and your term mark was reasonable for most of the units, except for the one on physics in which you had to use all those mathematical formulas to solve problems. In one way it was good to see that math was useful for something, but you didn't know which formula to use half the time. Here comes that questionnaire again. Let's see, what are you still enjoying? The labs win easily again—it was neat to work with those colourful chemicals and the little carts you pulled around to see how fast they could go. You write that the textbook should also contain neat little experiments a person could do at home. That class debate on whether we should continue to use coal to make electricity was also interesting, because you know that is an important environmental issue; yes, and learning about the ozone layer. You really disliked going over material already covered in junior high science—even in elementary. Why don't the teachers or the government get together and fix that? How many times do you have to learn about photosynthesis and food chains? They also need to make this course shorter or give you more time to finish it. It seems that we're only scratching the surface on topics. Just when you begin to understand something, it's time to move on. This could be a 10-credit course instead of five credits—that's what you're going to write as a recommendation for improving it. All in all, though, you enjoyed it.

Other Investigations into Student Experiences of Science Education

The findings of this analysis of student comments are similar to those reported by others (Blades, 1991; Eichinger, 1992; Ebenezer & Zoller, 1993; and Aikenhead, 1994). Students in science classrooms prefer enthusiastic, knowledgeable, and fun science teachers. They like lab work, teacher demonstrations, projects, films, and A-V materials and dislike quizzes, tests, lectures, textbooks, which were the most

commonly recalled techniques (Eichinger, 1992). Students dislike the seemingly endless writing in workbooks or taking notes from an overhead projector, practices which typify, from their perspective, science courses. In general, students find their science education lacking in relevancy and unconnected to their lives. Students prefer science teaching and learning in which they take an active and responsible part (Blades, 1991). According to the students in these studies, the classroom teaching practices that would help them like science are as follows:

- student–directed experimentations and explorations
- studying science–related issues as applied to local situations
- relating science concepts to everyday life

These following practices may not influence students' attitudes in a positive direction:

- extensive note taking
- reading the textbook, followed by answering questions
- memorizing, rather than understanding, content

Nearly 88 percent of the students in the study by Ebenezer and Zoller (1993) responded that they copied teacher's notes always or often. The handing out of notes is also a common practice in science classes. Almost 74 percent of the students never did experiments individually. About two-thirds of the students reported that their ideas were never used when planning science lessons. About 58 percent said they enjoyed science, but only 38 percent would like to study more science.

It might well be that current teaching practices are yielding the expected academic results as far as the achievement of good grades is concerned. If extensive note taking produces satisfactory results, why change? (Ebenezer & Zoller, 1993). According to these studies, the classroom atmosphere tended to dampen any spirit of intellectual adventure. The rapid pace, the large class size, and the machine-graded exams fostered the impression that science is authoritarian. Participation was not encouraged: there was little community, little discussion or collaboration among the students; and intense competition was promoted because of the limited number of high grades awarded. Content was presented piecemeal class by class, so students could not know where each piece fits into the large whole (Tobias, 1990). Such practices may be at the cost of losing fine, talented individuals to other fields and discouraging the average student from a continuing interest in science in adult life. The majority of those who reach college, hoping to do science, end up changing their minds (Tobias, 1990).

Chapter Five

Comparing the Sources of Information

There are several key areas in which the three sources of information intersect:

- the amount of content in Science 10
- teaching approach
- the basic textbook
- STS connections
- integrating the sciences

Content and Time

Many students recommended that there should be more time to cover the topics in Science 10. Students also recommended that some topics be deleted or delimited, but not for the purpose of saving time. These included the study of photosynthesis and food chains and webs, which they remembered had been covered well in earlier grades. Teachers also had a concern with the quantity of material to cover in Science 10; however, the teacher responses suggested different criteria for making decisions on deletions. They frequently mentioned topics without a direct tie to the subsequent courses, such as weather, should be delimited. Students did not mention this topic as one that they did not enjoy, but several students specifically mentioned weather as a study they enjoyed.

Teaching Approach

The component of Science 10 that the students almost unanimously enjoyed *and learned from* were the "hands-on" activities. The program of studies and the basic textbook reinforced this approach, and the teachers I interviewed supported activities in science programs, as a general principle. A point of discussion for some of the teachers was whether students can actually learn 'the content' using an activity approach. Some teachers saw laboratory activities as an opportunity to reinforce topics presented in classroom lessons, rather than a place to introduce new topics. Viewed in this way, the incorporation of activities became a time issue. The other issue that arose regarding activities was the lack of facilities and equipment and large class sizes making it impractical and even risky to carry out such activities.

Students did not like extensive note taking, answering questions from the textbook, or listening to the teacher talking for long periods of time. They enjoyed teachers who made the class fun and allowed them do things themselves. They enjoyed cooperative group work and discussions. From the student comments one can surmise that the traditional didactic methods of instruction were more prevalent in classrooms. The teachers I interviewed were all attempting to incorporate more activities, discussion, and group work into their classrooms and supported these directions in science education. The disincentive for two of the teachers was the time that it takes to use these approaches and the maturity level of the students. For the other two teachers I interviewed, these were not issues; they seemed more confident that students can learn through these techniques and did not view them as reinforcement activities for material presented in a didactic fashion.

The questionnaire mailed to teachers did not directly ask teachers about their teaching approach, but referred obliquely to this topic through their responses to Statements 5 and 6. Here teachers reported that they found it difficult to implement two aspects of Science 10—integrating the science disciplines and incorporating STS.

The Basic Textbook

Neither teachers nor students were positive about the basic resource for Science 10. Both responded that it lacked required information and that the information was difficult to locate. In addition, students found the questions at the end of the chapters too challenging. Teachers requested more practice exercises at the end of the chapters and did not appreciate having to prepare and locate supplementary resource material. The textbook authors developed open-ended chapter questions without definitive answers in order to foster higher level thinking-skill development. The discussion might distill to the question "What is the purpose of the basic textbook?" Teachers and students required a textbook for utilitarian needs, a place to easily find the answers to basic knowledge questions and to reinforce learning in a direct manner. The textbook developers, trying to accommodate pedagogical directions contained in the program of studies related to the learning cycle and constructivism, delimited direct instruction and didactic methods, using instead a discussion approach to many topics and weaving STS connections into the science concepts. Many teachers and students viewed these aspects as clutter that stood in the way of locating basic information.

STS Connections

Students reported that they like to know the relevance of what they are learning and are keen to learn more about issues that are reported in the media, particularly environmental ones. Teachers also support STS connections, largely because these topics motivate students by providing relevance for the science concepts. Teachers also understand the relationship of STS to the need for scientific literacy and endorse this aspect for that reason. However, teachers told me they are not incorporating STS into their teaching to the degree they would like because of a lack of confidence in their knowledge and the scarcity of relevant resources.

Teachers have various interpretations of STS. Most teachers understand STS as "applications of science". For example, when they teach about chemical compounds they like to mention how they are used on a daily basis (e.g., natural gas in the furnace), and when they teach about energy conversion, they would use a simple device that students are familiar with such as a hair dryer. Teachers also feel compelled to address issues related to STS, largely because of the media attention paid to environmental and ethical perspectives of society's use of science and technology. However, teachers feel much less confident in teaching in this dimension, both in terms of their knowledge base and appropriate instructional strategies. These topics require opportunities for research and discussion, a requirement which implies more loosely structured classroom configurations and the taking of the time to delve into the topic. When there are time constraints, then basic science concepts are given priority by teachers and the STS connections are provided as time allows. Some teachers do not believe 14- and 15-year old students in Science 10 have the cognitive maturity required to fully understand the complex issues inherent in STS connections. For example, Colin limited his students to identifying perspectives on an issue. There is also the problem of availability of resources to support this dimension of STS, particularly the latest research in a topical area such as global warming. Teachers were having to rely on the media to supply much of the relevant information. During the field validation, the teleconference conversations often turned to this topic, even when it was not on the agenda. Teachers asked each other for help and shared their sources for information on current issues.

Two aspects of STS that some teachers understand less, and probably consider less important, are related to the nature of science and the nature of technology. All teachers interviewed believed that students need to know about scientific inquiry and scientific ways of knowing and felt strongly about incorporating laboratory activities to help

students understand the role of evidence, replicability, and validity in scientific work. Teachers were divided on whether the historical aspects of science were of interest to most students. Colin was most keen about students knowing the roots of scientific knowledge and the various views of how scientific knowledge develops or how a particular theory in science came to be. For example, Dan emphasized what it means to do science.

The nature of technology is described in *Benchmarks for Scientific Literacy* (AAAS, 1993) as an extension of our "abilities to change the world", and the authors state that "we use technology to change the world to suit us better". The processes of technology involve planning and designing, using tools and techniques, and problem solving. The third dimension of the nature of technology relates to how technology has shaped our culture and its often unexpected impact on society. The nature of technology dimension of STS may be the least understood and endorsed by teachers, and the least well articulated in either the course of studies for Science 10 or the basic resource, *Visions 1*. The teachers I interviewed did not mention the nature of technology as an aspect of STS that they emphasized in the classroom; however, they did generally favour problem-solving skills, but not necessarily in the context of solving practical problems. The Alberta *Junior High School Science Program of Studies* (1989) outlines a set of skills for problem solving and provides a context for these through units of study. Roscoe (1993) reports that teachers of this program which he interviewed were able to successfully help students better understand technology through topics such as designing and building a device to perform a specific task.

Integrating the Sciences

Teachers find it difficult to integrate the science disciplines for a variety of reasons. They have traditionally learned and taught science as specialized studies. They also lack a background in all three disciplines, so the connections between the sciences were not apparent to them. This is not to say that teachers are opposed to integrated science, only that they find it difficult to implement. Respondents to the questionnaire were divided on whether Science 10 should be taught in a team-teaching mode in which the specialist teachers were assigned particular units related to their discipline background or as an integrated whole. Similarly, there was a difference of opinion among the teachers I interviewed. Colin was involved in a team-teaching arrangement after having found the single teacher approach to be less than ideal. Ann and Dan were in favour of

maximizing the integration between units and were fostering this through project assignments for students .

Students were not specifically asked if they favoured integration; nevertheless, several did make comments about the structure of Science 10 compared to the previous program, suggesting that their teachers might have prompted such discussions in the classroom. More students favoured the integrated approach of Science 10 than were opposed to it. Dissenting voices explained that they are not equally talented in all the disciplines of Science 10, so their mark was depressed because of poor performance in a particular science such as physics. Similar comments were also made by teachers in the questionnaire. They favoured the previous structure because students could choose the science they excelled at. Other students liked the efficiency of having to take only one science in Grade 10. Teachers saw the value of allowing students an extra year in which to choose specialized courses.

Comparing the three sources of information has provided validation for viewpoints expressed by each group and strengthened the themes that emerged from this investigation. The qualitative method involving interviews and class visitations offered an opportunity to find the depth of the opinions and feelings that teachers had about the Science 10 program and its implementation. The quantitative method utilizing a questionnaire to sample the opinions of a larger group of teachers provided data to corroborate the qualitative findings. The experience of the students in the classroom provided the triangulation that helped to further validate the "rightness" of the themes.

Emerging Themes

The following themes emerge from four sources of information: the in-depth interviews and class visitations with the four teachers, the responses of 82 teachers to the questionnaire sent to 100 schools, the analysis of the 600 response guides completed by students during the field validation of Science 10, and my interactions with teachers, curriculum developers, and others during the seven years I have worked at Alberta Education in the Curriculum Standards Branch.

Cooperative Approaches

The implementation of a curriculum change is largely up to the individual teacher; however the change can foster co-operative approaches. Teachers operate in a culture that fosters individualism and is classroom rather than community centred. The cellular

organization of schools means that teachers struggle with their problems and anxieties privately, spending most of their time physically apart from their colleagues. Because of the physical isolation and the norm of not sharing, observing, and discussing one another's work, teachers do not develop a common technical culture.(Lortie, 1975, in Fullan, 1982 p. 108). Prior to the introduction of Science 10, teachers in the majority of larger schools primarily taught one science program, for example, Physics 10–20–30, and if they interacted with other teachers to produce lessons and materials such as final examinations, it was with teachers who specialized in the same subject area. Isolation from colleagues can create uncertainty and focus attention on personal classroom experience that supports reliance on transmission pedagogies (Hargreaves 1989, p. 87, 88). When Science 10 was introduced, teachers were drawn out of their semi-isolation to reach out more to their colleagues and others when they had to learn science content that was outside their area of expertise or related to STS. Alternative viewpoints presented through changing curricular materials and interactions with colleagues can result in exploration of new methodologies (Hargreaves, 1989, p. 88). In some larger schools such as Dan's, there developed a strong co-operative effort among the teachers to adjust to the changing curriculum. In rural situations teachers were encouraged to make connections to teachers in other schools. The inservice and information sessions and teleconferences that Alberta Education held during the field validation provided a platform for teachers, particularly those from smaller isolated areas, to share ideas and build relationships.

Research provides confirmation that the quality of working relationships among teachers is strongly related to implementation. When teachers reach out and form close relationships with their colleagues, they report an ability to work through the problems that arose in the early stages of implementation, and they arrive at solutions (Berman and McLaughlin, Roesenblum and Louis, Miles et al, in Fullan, 1982 p. 72). The majority of Science 10 teachers contacted reported that they sought the help of colleagues when confronted with the new program. Solutions varied to the problems that arose, ranging from dividing up the topics in Science 10 among several teachers to take advantage of individual expertise, as in Colin's school, to forming an action research group in order to learn from one another about successful approaches, as in Dan's school. In Ann's and Beth's schools staff meetings and interactions, which were often ad hoc and informal, provided some of the required support; as well, they turned to a variety of sources such as books, the mass media, professional organizations, and personal contacts. Interactive professionalism is the term used by Fullan (1991) for

such involvement. He describes teachers and others working in small groups, interacting frequently in the course of planning, testing of new ideas, attempting to solve different problems, and assessing effectiveness—an interactive approach in the sense that giving and receiving help are the natural order of things. Teachers become continuous learners in a community of interactive professionals (Fullan 1991, p. 142).

When teachers see that others have accomplished a change, they are more willing to try it. During the field validation and implementation years, Alberta Education provided inservice and information sessions to teachers. Based on my personal observations, and the research into teacher journals by Krull-Romanyshyn (1996), these were most effective when practising teachers who had experienced the program in the classroom provided workshops for the other teachers.

The Pedagogical Shift

The introduction of STS implied a major shift in pedagogy. Teachers had to redefine themselves as science teachers and as facilitators of learning. Bybee (1994) identifies two major challenges for teachers implementing a new science curriculum with an STS dimension: (a) the need to learn new content and (b)coming to an understanding of the new conception of the learner based on constructivist theories (Bybee, 1994, p. 111).

Reeves and Ney (1992) describe a constructivist view of STS teaching and learning as focusing on the context of science as a human activity and a social institution among, and an interaction with many others (Reeves and Ney, 1992, p. 195). According to their analysis, teaching and learning that incorporate a positivist view of science focus on getting the facts straight, memorization, and intensive problem-solving practise remote from students' experiences; whereas constructivist teaching and learning are collaborative, multidirectional and interactive between teachers and students and among the students themselves (Reeves and Ney, 1992, p. 196).

Compared to the traditional science classroom, the STS classroom is more student directed and planned to encourage the construction of knowledge by students themselves. New content, methodologies, relationships, and evaluation techniques are required to address these dimensions of the science program. STS is not a revelation to teachers in Alberta, but there tends to be a narrow view of its applications. The many aspects of the nature of science are less well understood than practical applications; perhaps because of their own schooling teachers have internalized an objective model of science (Tobin et al, in National Science Teachers Association, Gabel [ed], 1994, p.

62). The nature of technology and the relationships between science and technology are other dimensions that teachers do not have a grounding in, based on their education. The issues aspect of STS is avoided by many teachers because of its complexity and the need to provide up-to-date resources and develop alternative strategies in the classroom. The maxim that teachers teach the way they learned has been corroborated by numerous observations. The intuitive knowledge that drives teachers' behaviour seems to be related to the hours of time they spent in classrooms during their own elementary and secondary education. (Tobin et al, in National Science Teachers Association, Gabel [ed], 1994 , p. 52).

When teachers try various methods of bringing STS into the classroom, for example class discussions, student–directed activities, and group work, they worry about covering the content and also about classroom management. Mitchener and Anderson (1987) identified three types of profiles of teachers implementing an STS curriculum. Teachers who felt the STS curriculum captured students' interest in real-life situations and who valued decision-making and group skills were more accepting of the (STS) curriculum; teachers who disliked the inclusion of social studies content and the lack of "real" science topics and who did not value activity, decision making, or group skills rejected the STS curriculum; and teachers who were concerned about the time and energy involved in implementing the curriculum altered it in various ways (Mitchener and Anderson, 1987, p. 351-369).

STS connections are supported by science teachers in Alberta, but it is an aspect they are challenged to interpret and to find information about to be well prepared to incorporate the appropriate topics into their lessons. Teachers like to feel in control in the classroom and knowledgeable about a subject because they believe that their students and the community expect this of them. While teachers support showing students the relevance of science, they consider content knowledge of the subject area to be the most important prerequisite for teaching. In the area of STS connections, teacher depth of knowledge does not match their knowledge of science concepts, largely because of their university studies, supporting resources are limited, and opportunities for inservice scarce. These are all roadblocks in the way of greater emphasis on STS.

Introducing a new way of doing things is risky for teachers as the outcome is unknown and the stakes relatively high—students, parents and community are holding them

accountable for good results in assessments. Beyond trust in themselves and self-confidence, teachers need role models and referents to show and reassure them that it is possible to institute a new order of things. Their only role models may be fellow teachers in the school, and if interaction is limited and they never observe colleagues , the referents to learn from are limited. For teachers who took part in the field validation of Science 10 and were involved in an intense inservice it was easier to take chances as they were, in essence, "trying out" the curriculum. In addition they had opportunities to interact and learn from a larger and more diverse group of teachers and other experts.

Specialized Disciplines

Senior high school teachers are socialized to loyalty to a specialized discipline of study that stems from the specialist nature of their undergraduate training and their success in that setting. This socialization of teachers into subject loyalty goes back to their experience as successful students, reinforced by their undergraduate training in specialist courses and exposure to a subject–divided pattern of teacher training (Hargreaves 1989, p. 57). The identities of teachers have partially been shaped prior to any preservice teacher training or entrance into the teaching profession. It seems that "how you learn a subject in college affects how you teach it" (Tobin et al, in National Science Teachers Association, Gabel [ed], 1994, p. 69). Most teachers learned science as separate discipline specialties through a didactic approach. A subject subculture provides security and a feeling of belonging, and is therefore comfortable, and difficult to move out of.

In beginning to teach Science 10, teachers had to redefine themselves as science teachers after many years of being identified as the chemistry or biology teacher in their school and community. Teaching outside of their discipline expertise is a concern for some teachers because they want to feel competent, which they define as knowing a great deal about a subject . Colin and Beth, whose major experiences were teaching a single scientific discipline, reported feeling uncomfortable when they did not know the answers to student questions. Ann, a teacher with junior high school teaching experience reported feeling more comfortable teaching an integrated science program. Dan who had taught a variety of courses, including a nonacademic integrated science program also experienced little discomfort in expanding his expertise.

Integration of the sciences was limited in the implementation of Science 10. Many teachers in large urban settings were specialist teachers who taught, for example, only

Physics 10, 20 and 30 for many years. If they interacted with colleagues, it was most likely with the other teachers who taught the same subject. Faced with teaching an integrated science program containing concepts related to biology, chemistry, and physics, some of these teachers felt a lack of confidence in their abilities, even after having taught high school science for 20 years or more. In addition, the introduction of STS connections implied additional content related to the nature of science, the relationship between science and technology and the interactions among science, technology, and society and the associated teaching approaches. Little in their preservice education had prepared most teachers for the delivery of this aspect. Largely schooled in traditional lecture halls and "cook-book" laboratories, these teachers found it difficult to adapt to the pedagogy suggested by the new programs. This problem was magnified in teaching Science 20-30, a program which requires a higher level of knowledge of science concepts from several disciplines and an understanding of STS connections from a variety of science specialty perspectives. Hargreaves (1989) states that subject –specialist socialization with feelings of loyalty, attachment and identification makes teachers reluctant to teach subjects different from their own. He concludes that poor–quality teaching outside of one's field is due not just to lack of knowledge and expertise, but also to lack of enthusiasm and commitment (Hargreaves, 1989, p. 57, 84).

Support Material

Teachers want, need, and benefit from tangible, relevant program materials that have been produced and tested in real classroom situations (Fullan, 1982, p. 60). Textbooks remain an integral part of many science classrooms and in many cases define the curriculum (Tobin et al, in National Science Teachers Association, Gabel [ed], p. 70). Many teachers were dissatisfied and disappointed with the basic resources produced for Science 10, particularly the textbook that had been custom published for the program. The expectation that everything required to teach Science 10 would be contained in a single textbook, and the teachers' guide, which had been field tested in the classroom, was far beyond what the publisher could deliver. Teachers required more practice questions for reinforcing concepts, for example, writing chemical formulas and balancing equations or solving problems. They also reported the text needed supplementation, even for basic concepts , and did not provide the content needed to address STS. Students too, had high expectations for the textbook. They wanted a resource that was easy to read and in which they could readily find answers to questions. They did not expect to have to go to other resources for information. They

complained that the questions asked in the book were too difficult, that the explanations were not sufficiently straight forward, and that the book used too many words to explain concepts.

Reading in traditional science textbooks typically means reading fairly short passages of dense material presented in a didactic fashion. STS additionally requires reading of more lengthy passages and reading of materials not contained in textbooks (Aikenhead 1988, p.24). Expecting a traditional format with terse explanations and many practice exercises, teachers and students had to shift their views of what constitutes resources for a science program. Most teachers supplemented the basic resource with existing materials or they developed their own. Some schools decided not to purchase the basic textbook for each student.

The development of the textbook was a collaborative effort between the Science Curriculum Consultants at Alberta Education and their consultation network, the leadership team of an educational publishing company and their consultation network, the teacher writers hired by the publisher, and the teachers involved in the field validation of Science 10. It is my opinion that most of the individuals in these groups were struggling to understand and interpret the new approach to science education suggested in the program of studies for Science 10. At the same time, changes were being made to the program of studies, based on feedback from the entire consultation network that included teachers, administrators, postsecondary representatives, members of business and industry and others. The end result was a model for a textbook that tried to accommodate these various requirements, written by authors steeped in traditional science education. It may have been doomed to fail.

Well–planned inservice programs can make a difference in teacher understanding of, and success at, making a curricular change, but experience in the classroom is the most important factor. Quality, comprehensive inservice programs have been identified as a key element in the successful implementation of new programs.

> Although curriculum is important, it is not important *by itself* (italics his); the mere change of curriculum without a change of teacher education, assessment tasks, resources and support is not going to have any dramatic effect on student engagement, interest and learning of science.
>
> (Matthews,1994, p. 20)

While the curricular documents provided a general sense of the direction of the reforms, they could not provide the specific procedures for getting there.

The other significant finding about inservice is that it must be provided to each individual teacher. The "trickle-down" model in which only key teachers receive inservice training in the hope that they will pass the information on to many others has not been effective (Bower, 1996, p. 58). None of the teachers chosen for this study had been part of the field validation or had received the intensive inservice program provided by Alberta Education to those teachers. Because all had completed postdegree–level studies, the teachers interviewed were knowledgeable about recent research in science education, while the teachers who completed the questionnaires were more representative of average teachers. All the teachers involved in this study had taught Science 10 at least once. The comments of the teachers indicated that they had a reasonable understanding of the intent of the changes, but that implementing those change was a challenge. Particularly, the teachers mentioned lack of background knowledge and inadequate resources as limitations to success. Bybee and Bonnstetter (1987) who surveyed 317 science teachers also found that most would incorporate STS topics if materials and instructional strategies were available (in Bybee, 1994, p. 139).

Each year that a teacher follows a curriculum it changes, so that after 10 years it may become, in effect, a different course. This suggests a need for continuing inservice or at least continuing communication between curriculum developers and teachers. Teachers reported that over time they made adjustments as they worked through the program, shaping it to meet their students' and community needs, until they felt confident in their abilities to deliver the program. The legacy of curriculum reform in science seems to be to place most of the responsibility on the shoulders of individual teachers, enculturated to a particular pedagogy and specialist-based science, working in schools that do not encourage innovation, and provided with minimal support by administrators, their professional organization, and curriculum innovators. "Working *with* teachers and not just *preaching* at them may be vital to...securing effective curriculum development..." (Hargreaves, 1989, p.58).

Classroom Management

Classroom management can become an issue when implementing a curriculum change. The teacher may be less in control of the knowledge base required for a new program and may appear more tentative. When Science 10 was introduced to Alberta schools, it affected virtually every senior high school science teacher because most teach at least some introductory high school science courses. However, their expertise is most likely

in a single discipline of science. At the time of the change, a very small minority of students were taking the nonacademic science program, Science 14, whereas most were enrolled in some combination of Biology 10, Chemistry 10, and Physics 10. The introduction of Science 10, in effect, destreamed the science program at the Grade 10 level so that it now is more like the junior high school science program. Teachers now are more likely assigned a group of students with mixed ability all of whom they have to prepare for the next level of study. Some teachers, particularly the teachers of physical sciences who had taught a more select group of students before the changes, had difficulty managing and accommodating a heterogeneous mix of students. Many students who previously enrolled in Science 14 are now attempting Science 10 because their parents do not value Science 14 as a course that will provide adequate preparation for future studies and careers, whereas Science 10 was viewed as a general science course, rather than as an academic science course students take in preparation for university studies in science. This perception further added to the challenge for teachers working with groups of students with mixed abilities. Three of the teachers interviewed reported that they investigated the background of their students in order to tailor the program to meet specific needs.

Changes are more successful if there is support from administration, particularly the principal. The principal strongly influences the climate of the school and assists in classroom management (Fullan, 1982, p. 72, 124). This was reinforced in the implementation of Science 10. Where administrators facilitated the cooperation of teachers by providing leadership and fostering staff development, by for example, scheduling common spare periods, providing the resources requested, and by giving teachers greater autonomy to use their professional judgment, there was a spirit of confidence and trust in the outcome of the change process.

The Content Issue

Teachers generally perceived that there was too much content in the science programs. Many teachers complained that there was too much material to cover in the Science 10 program of studies. In the field validation phase and early in the implementation, teachers did not have enough time to reflect on the changes and determine the best way to achieve them with their group of students. These comments gradually faded as teachers became more familiar with the topics and began to place the emphasis on the concepts that were required to prepare students for the next level of the science disciplines. The maturity level of the students and their skill and knowledge level,

particularly in mathematics, upon entering high school were also mentioned as factors in the perception that there was too much content in Science 10. With a more heterogeneous group of students teachers are faced with teaching to the lowest level of ability or leaving some students to cope on their own. Teachers want to do the best for their students; when rushed for time and with no possibility of second thought about, or adjustments to their approach, many teachers felt that they had no other choice but to remove some of the content.

Students concurred with teachers that there was insufficient time to cover all the content in Science 10 and strongly recommended that the course be lengthened. Some stated that they were just beginning to understand a topic when the teacher told them they had to move on.

In recent years science courses have become more like surveys of concepts because of the burgeoning amount of knowledge in the field. A fundamental premise of the AAAS *Science for All Americans* publications (1989, 1990) is that curricula must be changed to reduce the amount of material covered; that schools should not be asked to teach more content, but rather to focus on what is essential to scientific literacy. The use of themes as organizers in Science 10 and recommended by AAAS provides a focus for study that emphasizes key ideas and understanding over knowledge of details and facts. The teachers interviewed, while aware and supportive of themes, found it difficult to use them to integrate topics, and thus cover content more efficiently.

The issue of the overloaded curriculum is not likely to fade soon. As long as the general public equates factual knowledge with ability in science, the demand for the inclusion of more science topics will continue. As well, the community of scientists and science educators will continue to have difficulty choosing from this ever-expanding field the science knowledge that is essential for scientific literacy, and thus resist equating the implementation of encyclopedic curricula with the promotion of scientific understanding.

Consultation

It is essential to hear the voices of teachers. Teachers need to be consulted on curriculum changes that they will be required to implement. The question of "who decides" is a crucial one for teachers. When a centralized curriculum is changed, it is essential to bring those who are key to implementation, the teachers, into the process.

The controversy surrounding credits, early in the revision process to the senior high science program, led to a confrontational situation that had a profound negative effect on the implementation process. Although the curriculum development process was open, there was still the knowledge that Alberta Education had the final say on what would appear in the curricular documents and what resources would be chosen. These two situations led to a certain level of distrust between curriculum developers and teachers that may have caused them to be less than positive toward implementing the required changes. The process became much more open and broadened later on, which raised other concerns. Teachers wondered if their voices were being heard when so many other members of the community were at the consultation meetings.

Teachers also have to see the need for change. Teachers are only likely to make changes to their practice when they have become dissatisfied with their previous practice (Fullan, 1993). Most teachers were satisfied with the current science program for students entering Grade 10, and the change from Biology 10, Physics 10, and Chemistry 10 to Science 10 was not necessarily viewed as progressive. Initially there seemed to be few incentives (and seemingly large costs) to find out whether this change would be worthwhile. Even two years after implementation, half the teachers who responded to the questionnaire did not see the value of the integrated science program; however, the majority supported the STS dimension. Teachers provided greater support to Science 10 when they saw increased enrollments in subsequent programs after its introduction. Administrators, as well, had to see the benefits of the change to provide their support for implementation.

As well, teachers need to be given the opportunity to let curriculum developer know how a program is working in the classroom, *after it has been implemented*. Teachers were willing to talk to me and provide information through the questionnaire about their experiences with this new program in the classroom. While there was an opportunity for a smaller group of teachers to provide feedback on how the program was working during the field validation, I believe the other teachers, who were not part of the field test, need an opportunity to continue to dialogue with curriculum developers to provide their perspective on what could be improved in Science 10. Curriculum developers have to be willing to respond to the suggestions and make some changes. There are, of course, short term monetary implications since government agencies historically have not invested large sums of money in evaluating programs once implemented.

Student Input

Students can inform teachers and curriculum developers about what constitutes good science programs, and they should be consulted. My analysis of the student responses made it very clear that students want to be heard and have strong opinions about what they like and do not like about science courses. The most powerful message from students is that they enjoy and learn from "hands-on" activities, group work and classroom discussions. Also important to them is making sure that the science they learn is relevant and significant in terms of what is happening to the world. In other words, students favour nontraditional approaches and programs that relate to their lives.

Preparation for the next level of study is seen by teachers as a very important aspect of science teaching in high school. Beth felt the pressure of teachers of the Grade 11 courses to prepare the students well for them. Dan was concerned that Science 10 did not contain the topics that articulate best with the next level of study. Many of the respondents to the questionnaire expressed a similar sentiment. Teachers are well aware that most students and their parents are planning post secondary studies. Even if they know that the majority of their students will not pursue science subjects beyond high school, teachers feel the responsibility of preparing students for this possibility. Their academic background has ingrained the importance of "preparation for the next course". As well, the academic scientists at university traditionally had, and continue to have, a strong influence on the development of high school programs, exerting a pressure that reaches down to the grade 10 level. The National Assessment of Educational Progress data shows that traditional science instruction tends to negate natural interest in science, and cause some of the best students to pursue other disciplines (Matthews, 1994, p. 34). The lingering effect of the overriding goal of past curriculum reforms—to produce more scientists and engineers—continues to compete with the recent goals of preparing the very large majority of students, who will not likely use science in their careers, to lead their daily lives in an increasingly science and technology–oriented society.

Reflections on Curriculum Change

When a teacher is given an assignment by the principal, she/he is, in many ways, alone with it. Ultimately, she/he must understand what is required, assimilate the culture of the school and community, and adhere to a mandated program of studies in the interaction with her/his students. Schwab (1978) describes four commonplaces of education as equally significant in planning to teach: the learner, the teacher, the milieu

(school, classroom, community) and the subject matter. When the door of the classroom is closed, the teacher alone takes on the responsibility of facilitating the learning of 20 to 30 youngsters with a variety of needs, motivations, learning styles, and personalities. This complex task of teaching requires constant vigilance, split-second timing, and the ability to adjust and respond to student demands and questions as well as the external events that invariably interrupt each day's lesson. Each day a teacher may face hundreds of "response–demanding " situations. An appropriate metaphor might be a juggling act.

When a program has been in place for several years, a teacher has had the personal experience of having taught it, or the mentorship of experienced colleagues to call upon for assistance. The intended curriculum has become the lived curriculum. When a program has been changed, the teacher enters a new level of learning and accommodation. The tension between the curriculum-as-planned and the curriculum-as-lived increases once more (Aoki, 1986, p. 8). Several factors may come into play when a teacher learns that a program is changing. The teacher may experience any or all of the following:

- Loss of autonomy: an outside authority has decided that a program must change and the teacher has lost some control in the decision-making process. Making something mandatory can cause a natural resistance to it.

- Fear: the teacher may wonder if she/he can learn all that is needed to be successful in sailing in these uncharted waters.

- Uncertainty or questioning of the change: the teacher may not be convinced that a change is needed and therefore, may not be committed to carrying out the steps required to implement the program.

- Discomfort: as teachers struggle between what they have come to believe to be good science education and a new interpretation of science education there, is a natural tension.

- Added workload: change means learning new material and methodologies, revising lesson plans, choosing new resources, and most importantly, believing in the new order of things, all of which requires time for reflective thought, a rarity for teachers.

- A sense of rejuvenation: the teacher may view the change as a long–needed revision of a program or welcome it as an opportunity to become renewed. Taken positively, curriculum change can be viewed as a method to educate teachers, an opportunity to refresh their knowledge in a subject area and learn new pedagogical techniques.

- Greater connectedness: a new program requires the teacher to interact with other teachers in planning strategies and discussing the implications of the change. The extent to which a teacher can do this relates to the time available, the availability of colleagues within the school setting with which to enter into dialogue, and the confidence she/he has to approach others for help.

There are no easy or clear-cut answers to the dilemmas of teaching, but courses of action must be taken; choices are often between several less than optimal courses of action, then decisions are made. What problem-solving strategies do teachers adapt to implement a changed curriculum? Teachers may ignore the change, either unintentionally or intentionally. A teacher may believe she/he knows the intent of the new curriculum and is implementing it, but, in fact may not be. A teacher may decide that the old curriculum is better or that the new is too difficult or not worthy of implementation. Teachers may incorporate the new curriculum material into the old or add new content without discarding the old.

Eventually teachers have to make the curriculum their own. There are at least three dimensions involved in implementing a program: (a) new or revised *materials* (b) new *teaching approaches*, and (c) alteration of *beliefs*. Significant educational change can only come about through a process of personal development in a social context (Fullan, 1991, p. 132).

Implementing a new curriculum, like accommodating any change in our lives, is a cyclical process that involves the following actions:

- receiving information
- reflecting on it
- deriving meaning
- making a commitment to change
- taking responsibility
- taking risks
- reconciling discrepancies
- accepting the new order of things

Change is a difficult personal and social process of unlearning old ways and learning new ones (Fullan, 1982, p. 62). Educational change is a learning experience for curriculum developers, administrators, teachers, parents, and students. In any learning experience there are many stops and starts and many errors made. Teachers often expect perfection from themselves and others, and because they have come increasingly

under public scrutiny in recent years, this expectation has risen. Science 10 has the unenviable function of not only developing knowledge and skills in a science discipline in preparation for the next courses in biology, physics, and chemistry, but also of developing positive attitudes to science and an awareness of science as an enterprise, its relationship to technology, and the interaction of science and technology with societal issues. These dual goals of scientific literacy and knowledge of science were at the centre of the struggle teachers felt as they implemented Science 10.

There is little time for reflection in the everyday life of the teacher. Teaching decisions are often made on a trial–and–error basis with adjustments made "on the fly". Some individual teachers are more comfortable with this situation than others. Teachers must also deal with constant daily disruptions of the classroom routine as well as manage discipline issues and motivate students. Teachers today are faced with many serious issues that can limit their ability to successfully manage change. From unruly, disinterested students to demanding parents and a dissatisfied community, all within a culture of seemingly deteriorating values and ethics, there is a myriad of issues for teachers to tackle aside from their everyday management of student and administrative needs. The lack of opportunities for teachers to reflect, interact with each other, share, learn, and develop on the job makes it unlikely that significant changes will occur (Fullan 1982, p. 118). The lack of time and the feeling of not having finished one's work is a perennial problem experienced by teachers (Fullan, 1991, p. 121). When added to a changing curriculum, the stress of learning new material and incorporating new methods of instruction, the challenge that teachers face is daunting.

Deeper meaning and solid change must be born over time. One must struggle through ambivalence before one is sure, for oneself, that the new version is workable and right or unworkable and wrong (Fullan, 1982, p. 62, 63). If a process could have been devised in which only part of the new Science 10 curriculum was mandated for implementation each term, over a period of two years, it would have been more manageable to implement and there may have been more enthusiasm and support for the reforms. Most of the teachers implementing Science 10 also had to prepare for the revisions to Biology 20-30, Chemistry 20-30, Physics 20-30 and possibly Science 20-30 within the time span of three years. This rate of change seriously challenged the abilities of even the most energetic and savvy teachers.

Conclusions and Recommendations for Change

The following recommendations emanate from the findings and resulting themes that developed from this study.

- Provide teachers with more direction on the meaning of STS by providing effective and extensive inservice on the pedagogy and instructional strategies implied by STS. Teachers not directly involved in the field validation need the information the field test teachers received, in order to better prepare them for the required implementation.
- Use the expertise of practising teachers as much as possible in the development of the curriculum, learning materials and inservice programs. These materials should ideally be developed by experienced teachers who have accumulated years of knowledge in their "craft", with the advice of students on what they find to be important connections to science.
- Continually work at building the working relationship between practising science teachers and curriculum developers at departments of education, and provide subsequent support and communication after implementation. Teachers left on their own with little support are not likely to feel confident in their abilities to provide the program envisioned.
- Give students more opportunities to voice their opinions in the curriculum change process. They are directly affected by the change, they want to give their opinions, and their opinions are valid.

Educational change is challenging, stressful, dynamic, and sometimes frustrating. It always requires hard work, but ultimately can be very rewarding.

> Real change, whether desired or not, whether imposed or voluntarily pursued represents a serious personal and collective experience characterized by ambivalence and uncertainty and if the change works out it can result in a sense of mastery accomplishment and professional growth."
>
> (Fullan 1982, p. 26)

Krull-Romanyshyn (1996), based on her analysis of journals written by science teachers involved in the field validation of the new science programs in Alberta, reported that only a few teachers welcomed the change process or assumed a leadership role in providing guidance to others. A small minority vehemently opposed the changes and resisted efforts to examine their beliefs and feelings. The vast majority of teachers took a "wait and see' attitude and underwent an "evolutionary" process that resulted in

their eventual acceptance of the change (Krull-Romanyshyn, 1996, p. 146-7). Change is a highly personal experience—each and every one of the teachers who will be affected by change must have the opportunity to work through this experience (Fullan 1982, p. 113). The strength of the situational-interpretive approach to investigating how individual teachers implemented Science 10 is that it allows us to listen to teachers' in a personal way. The many teachers I met through this study and in the course of my work at Alberta Education, shared common concerns but used individual and unique approaches to working things out to meet local and individual needs.

Teachers have the greatest direct impact on students in the school system. The interpretations that teachers give to subject matter and the classroom atmosphere constitute the curriculum that students actually experience (Schubert 1986). The production model of curriculum implementation, in which teachers are merely viewed as "technical practitioners" is not useful (Aoki, 1990). Teachers should be viewed as curriculum adapters. Implementation is not the following of orders, but the development of learning experiences based upon knowledge derived from interactions with learners (Schubert, 1986). We need to nurture the interpretive power of teachers and learners and their ability to grow as they interact with the curricular documents and resources, with one another, and within a community of learners.

Teachers exhibit amazing resiliency when faced with the stress of a major curriculum change. They accommodate it with resourcefulness, as they do the myriad of accommodations they make, such as the increased demands for accountability, larger class sizes, pressures to learn about and incorporate computer technology into the classroom, etc. They make accommodations to the extent that they understand the change, accept and believe in it, and within the limitations of their inherent skills and the support systems they have in place. The reformers have already assimilated these changes for their purposes and worked out a reformulation that makes sense to them. (Marris,1975, in Fullan 1991 p. 31). Curriculum developers must not deny teachers the opportunity to work through the changes and even to reject initiatives in the process. It is only in making what is someone else's their own, that teachers can assimilate the reform. They must see that it can work for them, and that it is a worthwhile pursuit.

Suggestions for Further Study

It has been three years since Science 10 was implemented. As teachers and students interact with a curriculum, it changes over time. It would be interesting to do a similar study of Science 10 in a few more years time. Would teachers still find there is too much content? Would they be more successful at integration? What resources would they be using to supplement the current resource? Would their understanding of STS have changed?

The question of scientific literacy and what kind of science program students need is still not wholly answered, and has implications for teacher beliefs and commitment to reform. Is the purpose of science education to prepare students for the next course and subsequent careers in science, technology and engineering, or is it to prepare future citizens to function in society? This needs further discussion,

The most radical change in the senior high school science programs may have been the introduction of the integrated academic science program for Grade 11 and 12 students, Science 20-30. Initially, there was concern among many teachers and academic scientists that it would draw too many students away from the individual discipline courses. In fact, it was designed as an alternative to studying in disciplines because most students do not need an in–depth knowledge of biology, chemistry and physics in order to pursue, for example, postsecondary studies, jobs, and daily life. Even within the scientific discipline programs, the majority of such students are enrolling in only one science program, usually biology. Such a singular approach may not foster scientific literacy for dealing with decision making. Because such a small minority of high school graduates go on to study science at the postsecondary level, there is potentially a large cohort of students who would be candidates for this program. Academics, teachers, and administrators have largely rejected this program, and today less than 10 percent of high school students are enrolled in Science 20-30, when up to 50 percent potentially could benefit. What are the reasons for their rejection? However, there is still a small number of teachers who choose to teach this program and actively promote it within their communities. What motivates these teachers to do this, and how are their belief systems and vision regarding science education different from other teachers? It would be interesting to investigate.

In 1995, the Council of Ministers of Education, Canada (CMEC) adopted the Pan-Canadian Protocol for Collaboration on School Curriculum with the goal of improving and harmonizing curricula in Canada. A Common Framework of Science Outcomes K–

12 is the first joint project undertaken as part of the protocol. The result of this work could mean further substantial changes to the senior high school science programs in Alberta. At this time, Alberta is the only province with a curriculum that so explicitly integrates the learner outcomes for the STS dimension into the program of studies; in other jurisdictions, STS goals are written into the philosophy and rationale and the suggested teaching approach. What influence will the work done in Alberta, in consultation with teachers, have on the development of the Framework? If there should be a downplaying of the STS dimension, will teachers in Alberta support the Framework? The progress and outcome of this first joint project would be an intriguing study.

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Appendix A

- Letter to teachers confirming participation in the study
- Agreement between the researcher and the participant
- Personal grounding questionnaire

Dear :

Thank you for agreeing to take part in the study I am undertaking to investigate the lifeworld of the Science 10 teacher. I am looking forward to getting to know you and to better understand what it is like for teachers to experience a curriculum change. Hopefully, what we learn together will help us and those who read the results of the study to reflect on the new science programs and their implementation, and perhaps make the transition easier for ourselves and for others.

So that I can better understand the personal background and experiences you bring to the classroom this year, I am asking you to fill in the attached questionnaire. All information will be kept confidential. We will use your responses as a starting point for our first conversation. Part of the questionnaire includes some questions about when would be the most convenient times for us to get together.

Also enclosed is a form outlining the ethical considerations that will be observed for this study. Please sign it and date it and return it to me along with your questionnaire in the envelope provided.

I look forward to hearing from you soon.

Sincerely,

Stella Shrum

AGREEMENT BETWEEN THE RESEARCHER AND PARTICIPANT IN THESIS RESEARCH: THE LIFEWORLD OF THE SCIENCE 10 TEACHER

Researcher: Stella Shrum

Purpose: M.Ed. Thesis Research

Research Problem:
What can be learned from the experience of teachers implementing Science10 that can help to better understand the lifeworld of the teacher during a curriculum change?

Research Methods:
• literature review
• interviews and visitations with teachers implementing Science 10 in Alberta schools
• analysis of curricular documents, particularly the Science 10 Course of Studies

Description of the Study:
The participants will be five teachers of Science 10. Individual interviews will be conducted with the teachers during the course of a semester, over a period of about four months. Visitations will be made to the teachers' classrooms while lessons are in progress.

Ethical Considerations

• strict confidentiality will be maintained and no personal information that might identify the participant will be made available to anyone, unless mutually agreed upon
• the transcripts and interpretations of interviews will be shared with the participant and an opportunity will be provided to revise any information not agreed upon
•the final draft of the thesis will also be shared with the participant so that she/he may provide further input, prior to publication
•the participant has the right to opt out of the study at any time.

As the researcher I agree to the description and conditions described above:

Signature:_____Date:_

As a particpant in this study, I understand :
•the purpose of the study and my role in it
• the ethical considerations
and agree to take be part of this study as outlined above.

Signature: _____Date: _____

PERSONAL GROUNDING QUESTIONNAIRE

Current teaching assignment:
- subjects taught

- number of students you are teaching

- size of school

- facilities and equipment available for teaching science

- makeup of science department

- description of the school community you are in

- your role in the school

Education:
- elementary and secondary

- postsecondary

- degrees, diplomas held

- special courses taken

- teachers, professors that have had a particular influence on you

Experience:
- past teaching assignments

- other jobs or careers

- professional development activities

Involvement in the curriculum development process:

Family responsibilities:
-spouse, children, parents, pets etc.

Extracurricular activities:
-hobbies (type, length of interest)

Particular events or persons that have influenced your views on teaching science:

Times and dates over the semester that are most convenient for me to be involved with this study:

Appendix B

- Sample transcripts

A: Exactly. I would say that they just haven't had, well sometimes they tell me that they have not taken that, and I come back with the fact that well it is in the program of studies so you must have taken it, but maybe it is not something that you focused on, or that you were able to grasp back a year ago.

Q: You also teach 20-level.

A: Right.

Q: How well did you feel that Science 10 prepared students for 20-level sciences?

A: It prepares them if they are in fact able to remember the content. I find that in 20, teaching 10 as well, I often go back and in Science 10 you cover this, do you not remember, and quickly go over it. Sometimes I have to just stop and cover it again, as if it was for the first time. The skills are in place. I can get microscopes out at the 20-level, and I do not have to go through how to focus and make a slide, and all of those things. I think that at least in our school, we've done a good job of getting them prepared skills-wise, but the knowledge. Well, if someone gets fifty percent in Science 10 they can move on, so knowing fifty percent does not exactly prepare you really well for the next level.

Q: Do you think it has something to do also with if you are doing the "hands on" things it tends to stick with you, whereas if you are just talking about things you may not remember.

A: No question. I find that even within the same course the same year. If you are in a hurry for instance, and you have to cover this concept by this date, or whatever, I usually do a lab and tie in maybe a video, as many areas as I can for the one concept. If you are in a rush and think, okay, I am just going to show them this video or just provide them with these notes, but we are not going to do a lab on it. For sure. You can even see it two weeks later on a unit test. So, you have to build in a theme where you can at least do a lab, and show some video, do some research on as many topics as you can, but you have to try to tie the concepts together because you do not have enough time to do that for every single concept. You have to link them together. That is what the Alberta Clean Air Strategy was so good for. It linked chemistry concepts and biology concepts together. So, it was a big project. It took me four classes, which is a lot of time.

Q: But you thought it was worth it.

A: Yes. It did a good job. They built models of chemicals, so that reviewed some of the chemistry. They had to talk about the molecular, ionic, we had them go back to those terms in chemistry, and this was the linking to biology. So we did not have them do a lot as far as biology was concerned, but we talked about acid rain, and those things — how it affects the environment. I found my students had a really good background on that from junior high. They seemed to really focus on the environmental aspect. So they could handle that no problem.

Q: That must have been the last unit in junior high.

A: And they can remember back for sure.

Q: Plus, it is more personally relevant.

.....

Q: In some ways that has maybe changed a little too, from when we were going to school. There was not as much concern about that — about whether it was relevant or meaningful.

A: Yes, maybe when we went to school. But when I first began to teach I always hunted for those examples.

Q: Do you think that is a personal kind of thing?

A: I do not know teachers who do not do that. I really do not. I think how can you not. Science is a study of life and science studies principals that are in nature so, the world around you, really. How it works. So, I am sure all science teachers have done that.

Q: How important are lab activities in a high school science course?

A: I think that is really important, too. I think part of their science education is to learn to manipulate equipment, to heighten their own skills in observation, to understand scientific methods — that they know that they have variables they have to control. Just to have a taste of what real science is. If we do not do a lab. Well that is what science is. All the knowledge that has come out of this is through experiments, so for them not to do any. Sometime, though, they do get sacrificed because of the sheer knowledge volume we have to go through sometimes. I find that frustrating. I would love to teach a course sometimes like the enrichment science. Just going on some field trips, have more labs where you can spend a bit more time just doing instead of just a little bit of doing and then we are moving. It is very important to me — labs.

Q: You talked about a great deal of material here. I am getting the feeling that you feel responsible for getting that material across to the students. What do you see as the students' role in obtaining the material?

A: They just do not do much homework. I give marks for homework. I threaten with pink slips — "If you do not get homework done you are going to get to study hall!" — but they are not good at homework. I have not been compromising with the grade 10's. I have with the 11's, but their attendance is not good. They are responsible for learning it. I do not know, I found that there is a lot of gaps that way. They do not have a strong work ethic, so sometimes the only way I can get them to understand is to be there. They were supposed to do some of that weather unit on their own, and very few of them did. The marks from their tests were dismal, and I reviewed a bit, but if they have not done any of their reading from their book they were a mess. I do feel responsible and it is because of their lousy work ethic, I guess.

Q: And partly you being a very responsible person. I mean, you take it to heart. You do not want them to do poorly. You want them to do well.

A: That is true. And if they do poorly on an exam, it is very seldom I will put the blame on them. A lot of times I think maybe I am lenient especially if the class average is not very strong, and that is what happened in that weather unit. So, it worries me a lot. So, I am really thinking about what I could do now with the semester coming up. How I could change things. They are a different group, too.

.....

Q: Talk a bit about what it is like in your classroom. The typical approach you take — something about your philosophy of teaching.

A: I like to start off a day with going over the homework. Monitoring the homework. If they are putting the work on the board, I would go around and check to see whether or not they had made an effort to complete the homework. That typically takes up the first portion of the class. I would also, at this particular point in time, as I am going through the homework, try to identify any problems. Most of the time that is where the concepts are taught, and reinforced, and repeated, and questions are taken from the students. Most of my teaching is done going over the homework. Answering questions, interacting with students, asking them questions, reinforcing things, getting them to write notes. Today there are no examples on the board. Typically, there would be a set of notes that goes with this as well, to have them write things down in their notes. You are trying to get them to focus on certain things and we typically try and focus on it throughout essentially an activity base, and if you think of homework as an activity, and trying the ideas, and testing the ideas that they have in their heads, and doing a bit of a constructivist type of things. Having it put on the blackboard, I think, is a way of dealing with a kind of a constructivist type approach, as well. You see how they are constructing their answers. At the same time, you are dealing with so many pedagogic things with them, as well. Trying to get them to focus on things. If they have ownership on what it is they are more likely to pay attention. Getting grade 10's to pay attention and to learn and to learn how to learn is something that we keep coming back to in Science 10 over and over again. I think we are finding that with the Science 10, that has been more difficult than the difficulty we had with the Chemistry 10, Physics 10 and Biology 10.

Q: Any thoughts on why that might be?

A: Only because I guess the kids before selected it themselves. They selected to be in chemistry, physics and biology. it was their choice, and who do they have to blame but themselves. Whereas if they are in chemistry and feel they are not doing well, it was not their choice. They had to take it because it was part of Science 10, and we get that kind of attitude coming from them. And therefore, we have to struggle a little bit more to get their attention than we did before. It is always there to a certain degree. I think we are just finding it is to a larger degree than it was in the past. It is a more heterogeneous group than perhaps we had before, and some students do better in certain portions of the course. They pay attention more in certain portions of the course. Tune out in certain portions of the course, and so on. I had a little bit of a set to with a student after class today because he just does not have the same sort of attention span as most of the people in class. He kept saying over and over again "I pay attention." I said, "Well, I do not see evidence of that." Finally he blurted out, "I am always listening." I said, "Oh, that is what you mean by attention. I can see the faces and eyes of everybody else in class, and not you." I think part of my lesson in terms of going over this is to see, to continually kind of monitor who is paying attention and who is not and try to get them on tap. To raise their level of learning, of their skills of learning to a higher level, so that they are going to be successful at the 30-level.

Q: That would require quite a bit of communication between teachers to come to those decisions. How do you find time in your busy schedules to have these discussions? Are they group meetings? Or are they just as you are walking by?

A: The first year we met every Friday at noon, plus all of the other informal discussions that went on, probably added up more than what happened at noon hours on Fridays. For the last two years, we have a Science 10 meeting every second week. We have, as a group, the physical Science 10 teachers meet on a Friday, and the biological Science 10 teachers meet on every second Wednesday. On the ones in between we have biology, chemistry and physics meetings as required. Sometimes they are canceled, because there is nothing really pressing that we have to get done. We have common exams. We have common labs. We have to decide what labs we are doing and when the lab is going to be done. What particular common exam we are going to be using. What content we are covering. A lot of the decisions are kind of in general made at the beginning of the year — how far we are going to go in the course. Some of the specific decisions are made as we go along and we have to adjust and, that is what teaching is all about, being flexible.

Q: Getting back to your day-to-day activities, I know at the beginning you mentioned how important STS connections are to you, and that was one factor that caused you to decide to go with the team teaching. Could you talk a little bit about how you are approaching that aspect of the program.

A: I think we have tried to move from a more formal to, in our long term goal, from a less formal to a more formal type of thing in terms of the STS. I think a lot of it initially was with the teachers teaching the course and finding out what the content was like and bringing in their own type of STS connections in a verbal type of fashion.

Q: You talked a bit about preparation for 20-levels and that was part of the question. I think you covered that. Content — yes — you generally feel there is too much and that fits in with preparation for 20-levels. You want a good solid base so you are thinking of what you can cut back so that you are doing the essential parts to prepare them.

A: Right. And giving them the repetition that they need on some of these things because that is how kids learn for a large part. I think that is the success of the sciences, is that you can repeat it in the laboratory, you can repeat it on a test, you can repeat it on a worksheet, you can repeat it in a discussion, and so on. I think that is how we have kept the participation so high in sciences in Alberta in the past is to be able to do that type of thing. If we lose that kind of repetition through a whole variety of context, including AV which I did not mention before, and now add in computers and so on, then the participation is going to go down. I think I mentioned to you last time that we are very proud of the participation level in our school here in the sciences.

Q: Particularly chemistry, you mentioned.

A: Just fantastic participation levels. I think in large part it has to do with our variety of instructional techniques that we are using with these students. But that takes time.

.....

Q: So within your school, each teacher does the whole program of Science 10. In some schools they split it up where one teacher might do the physical sciences, another the biological sciences.

A: We tried that and had incredible resistance from the community. Students did not like it.

Q: What sort of reasons did they cite for not liking it?

A: I do not know. I was not particularly involved in that phase. I know the general consensus was dislike. Now it may have been just having so many more teachers.

Q: That is multiplied in grade 10 already.

A: See, if you had three different teachers for Science 10, and possibly four, that would be four different marking styles, four different classroom styles, the whole discipline control angle would be different for each person. So, it was just something resisted quite a bit and this year we did not do it.

Q: Why did you do it initially?

A: I think the original situation was probably pretty typical. All of our science teachers are much more confident in specific disciplines. This particular school that I am in resisted the Science 10 change because of that. People were very uncomfortable with physics, extremely uncomfortable. Chemistry, not so much. Biology, almost only the physicists were uncomfortable with biology. It was interesting that way. That is one of the reasons we formed this action research group. We have members from each of the disciplines. We believe that they could teach others of us techniques and tricks that would really make the whole thing better.

Q: So how do you arrange that? Do you meet periodically? Exchange materials?

A: We meet just about every week. We meet weekly on Mondays at noon. We have sort of an agenda of sorts that we are working towards. What we are doing say this coming week is looking at generally some evaluation questions for chapter one. They have kind of reached a point where they are starting to branch off and look at serious questions about teaching itself. What is the best way to approach science. Is it from the big picture to the small detail or from the small details to the big picture. Questions like that are causing them to look at what they believe to be true about teaching itself. That is going to be quite informative to see how that turns out.

Q: So thinking in terms of the big picture, that would suggest that you could integrate many disciplines within the program. Do you see teachers moving that way? How about yourself? What approach do you take?

A: I happen to be one of the few who say integrate the thing. Do the chemistry, physics and biology all at the same time. That is my belief. It is very difficult to do that within the structures that are set up. We have a common final for all our classes. The final's always working there. You have to make sure your students have done all the stuff for the final. What we did was in this action research group is develop two models that one could have. One being having your common theme, say energy transformation and transfer run through the course and feed in

chemistry and physics as the topics evolve. Alternatively, have the same theme, but run it throughout each of the units. They elected this year to take it through the units, sort of as a transition. What we would like to do is get to the point where we have the theme running through a series of activities and then just feeding in information for each of the sciences. That would be our goal, we kind of anticipate that being done down the road away. People are just becoming comfortable with the idea of a theme. I can actually get you a copy of that diagram.

Q: I would not mind seeing that. Well, maybe when I visit your school.

A: The action research group has been really powerful for the five of us that are in the group. Mainly because it affords a chance to talk about teaching Science 10, and tricks and ideas. What will happen is that one person's idea will spark another idea. For example, one of the first issues that came up was that one of the teachers said "Well, I am tired of being an expert. I always feel that I have to have the answer every time a student has a question, and I do not know what to do anymore. I do not have the time to research all this stuff." It is getting quite detailed. Now it is biology, physics and chemistry. It is moving people beyond their knowledge base. Another teacher said, "Well, that used to happen to me, too. But, now I just tell them to go and research it on their own." A third teacher said, "Yeah, but then the question dies at the door because they will not pursue it." And a fourth teacher in the group said, "Well, what I did last time is ask the student to write out the question. Spend some time and write out what that question meant and then bring it back." In a sense, what happened is the student made a commitment to the question by doing that. Together with the student, the teacher pursued it. I believe the student called the science hot line and found the answer that way. It was interesting how that idea kind of came around. What that did in the group is re-focused people on one of the key skill areas, I believe, in the whole science program now, is the idea of defining questions. Almost everybody realized that we have always been defining the questions for the student. Maybe it is time the students defined them. That is why we originated the twenty-five questions, is to get the kids starting to question. Each of us had added a component of that into the program. The kids are posing more questions.

Q: It also sounds like you are redefining the teachers' roles somewhat in this group.

A: Yes. That is one of the outcomes that can happen in an action research group.

Q: It sounds like the introduction of Science 10 has had a rather profound effect on some of the staff in your school. Would you say that?

A: Yes. I think that for some people, actually two things happened. Prior to this action research group, the first response was to merely take what we had been doing in Biology 10, Chemistry 10 and Physics 10 and transplant it. In fact, when I look at the final exam I tend to see a whole bunch of questions that used to be in the old program. Just kind of moved over and dumped them. Then, as time went on, people became more comfortable with teaching the course, and there has been a slight evolution. But nobody has really, until this year, started to look seriously at the division and methodologies that are implicit in the program, and that is what that group is doing. It is interesting, the other five members of the department, some of them are just going, "I am not going to get involved. I am not going to change the way I teach." What it had done for me is it has really highlighted some structural things that are in the nature of teaching. The idea that each of us goes off to our own classroom, and does our own thing, by ourselves, and across the hall

someone is doing their own thing. So, I will be making up exams for chapter one, and they will be making chapter one exams, but we never talk about it. That type of thing. I think that what is starting to really come out in this is an awareness that people have been isolated. Some prefer it that way, others would like to bridge that. I have heard it said by other science teachers that well we really have to all teach exactly the same stuff, because we do not want the community to say, "So and so is teaching this and you are teaching that, and it is not fair to the kids." At the same time, people resist teaching alike. They all say, "Well, I have my way of teaching and I am not going to change." This group of five has come around to say, "I have my own way of teaching, but I would sure like to learn how you do what you do and see if there is anything that I could use."

Q: Any thoughts on the differences between teachers in that way? Why are some really wanting to get involved in this process of change and others resist it? What might have been a catalyst, aside from imposed change in your school, to end up at this point where you are now with this research group really looking at what they are doing and how to do it better?

A: I think the research group came about as a result of people having that forced change from the outside and not being content with just transplanting old ideas. It just did not seem to fit right. It did not flow well. The course became something that students did not like and teachers did not like. I do not know whether it was the teacher who did not like it so then they did not make it a very interesting course and the kids did not like it as a result, or whether there was something just in the course that did not seem to click but, just that dissatisfaction. It did not feel right. It was not going right. There had to be another way — a better way. One of the things we did initially is we looked at why people taught science. Why did you come to teach science? What was it about science? Everyone indicated it was sort of that love of the area, the information, the knowledge, the symbols. I have a sneaking suspicion, that for many science teachers it is not the act of doing science that is important, so much as all the little trivia that is attached to it. We all have our stories of biology that we like to tell about this and that. Just this incredible knowledge that is available from science, but the actual conducting of scientific research is not something that probably drew people to the sciences. I suspect that most of the teachers have not done true science, from the point of framing a question all the way through to the answer. They have only done the traditional "do the experiment after your teacher's told you" approach. I think that is a real difference.

Appendix C

- Letter to science department heads of schools
- Science 10 Teacher Questionnaire

March 10, 1995

Dear Colleague:

I am a part-time graduate student at the University of Alberta and for my thesis study I am trying to find out what it is like in "the world of the Science 10 teacher". Science 10 has been in schools now for three years and, as with the introduction of any new program, teachers have had to make the greatest contribution to its implementation. What do teachers think of the program? How is this related to their past experiences? How do students like the program? Is it preparing them well for the future? These are some of the questions I hope to address in my study and if, you as a teacher of Science 10, could help me answer them I would greatly appreciate it. I hope that this study will provide some insights into the process of implementing new science programs and the role of the teacher in this process.

Please take a few minutes to complete the questionnaire I have prepared and return it to me in the self addressed envelope. If there are several teachers of Science 10 in your school who could complete the questionnaire that would also be much appreciated. Please photocopy as many as required. My preference is that each questionnaire be completed individually and not as a group, because of the focus of my study on the personal experience of the Science 10 teacher.

You may also know me as a consultant working for Alberta Education. Please be assured that this thesis work is a personal project related to my graduate program at the university and not related to my work at Alberta Education.

Thank for your assistance.

Sincerely,

Stella Shrum

Science 10 Teacher Questionnaire

Personal Information

A. How many times have you taught Science 10?
1-2 ___3-4___5-6___7-8___ 9-10___ 11+_____

B. What is (are) your area(s) of specialization based on your teacher training?
biology___ chemistry___ physics____science_____
other (please specify)_____

C. Prior to teaching Science 10, what subject(s) did you mostly teach?
biology__chemistry___ physics___ junior high science_____
other (please specify)_____

D. How many years of teaching experience have you had?
1 -2_____3 - 5_____6 - 8 _____ 9 - 12 _____13- 15_____
16 -20_____21+_____

E. Have you had any previous experience teaching integrated science, for example junior high science or Science 10 in another province?
yes___ (please elaborate)_____
_____

no____

Twenty Statements about Teaching Science 10

Based on a scale of **1** (strongly agree) to **5** (strongly disagree) respond to the following statements. Use the space below each statement if you wish to elaborate on your answers.

1. The science concepts in Science 10 are appropriate for Grade 10 students
strongly agree 1 2 3 4 5 strongly disagree

_____

2. The skills in Science 10 are appropriate for Grade 10 students
strongly agree 1 2 3 4 5 strongly disagree

_____ _____

3. The STS connections in Science 10 are appropriate for Grade 10 students
strongly agree 1 2 3 4 5 strongly disagree

_____

4. Science 10 contains topics that are important for scientific literacy
strongly agree 1 2 3 4 5 strongly disagree

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5. I am able to teach Science 10 as an integrated science program rather than as a series of mini science discipline courses
strongly agree 1 2 3 4 5 strongly disagree

---

6. It is easy to integrate the STS connections into the science concepts in Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

7. There is enough time to teach all of the concepts in Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

8. I feel adequately prepared as a teacher to teach Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

9. I often seek assistance from colleagues when I encounter difficulty with unfamiliar topics in Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

10. I enjoy teaching Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

11. Science 10 is best taught by two or more specialist teachers in a team teaching mode
strongly agree 1 2 3 4 5 strongly disagree

---

12. There is not much I would change about Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

13. The resources, including the textbook, to support the teaching of Science 10 are adequate
strongly agree 1 2 3 4 5 strongly disagree

---

14. Science 10 prepares students well for 20 level science courses
strongly agree 1 2 3 4 5 strongly disagree

---

15. Students are doing reasonably well in Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

16. Science 10 is too difficult for the students enrolled
strongly agree 1 2 3 4 5 strongly disagree

---

17. An integrated program like Science 10 is better for students than a single discipline program (e.g., Biology 10, Chemistry 10 or Physics 10)
strongly agree 1 2 3 4 5 strongly disagree

---

18. TheSTS emphasis in Science 10 improves students' decision-making abilities on issues related to science
strongly agree 1 2 3 4 5 strongly disagree

---

19. Students generally like Science 10
strongly agree 1 2 3 4 5 strongly disagree

---

20. Parents and the community have reacted positively to Science 10
strongly agree 1 2 3 4 5 strongly disagree

Provide any further comments you would like to make about your experience teaching Science 10 in the space below.

Thank you so much for your cooperation in filling out this questionnaire. If you are interested in speaking to me personally about the topics in this questionnaire, please include your name, address and phone number below:

Appendix D

- Student Response Form

SCIENCE 10
STUDENT RESPONSES TO FIELD TEST UNIT

Unit 1: Energy from the Sun

Publisher: Gage Publishing Limited

School: _____

Date: _____ **Age:** _____ **Sex: Male:** _____ **Female:** ____

What topics did you enjoy the most in this unit?

_____

_____

_____

_____

_____

_____

_____

_____

_____

What topics/activities did you enjoy the least in this unit?

_____

_____

_____

_____

_____

_____

_____

_____

_____

What changes would you like to see in this unit?